COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 11, No. 11 | MAY, 1940 | 25c a copy

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Grindability Index Determination by the Ball-Mill Method

Higher Pressures in Industrial Plants

Influence of Copper With Respect to Corrosion in Boilers

Intermittent Burning of Gas and Pulverized Coal

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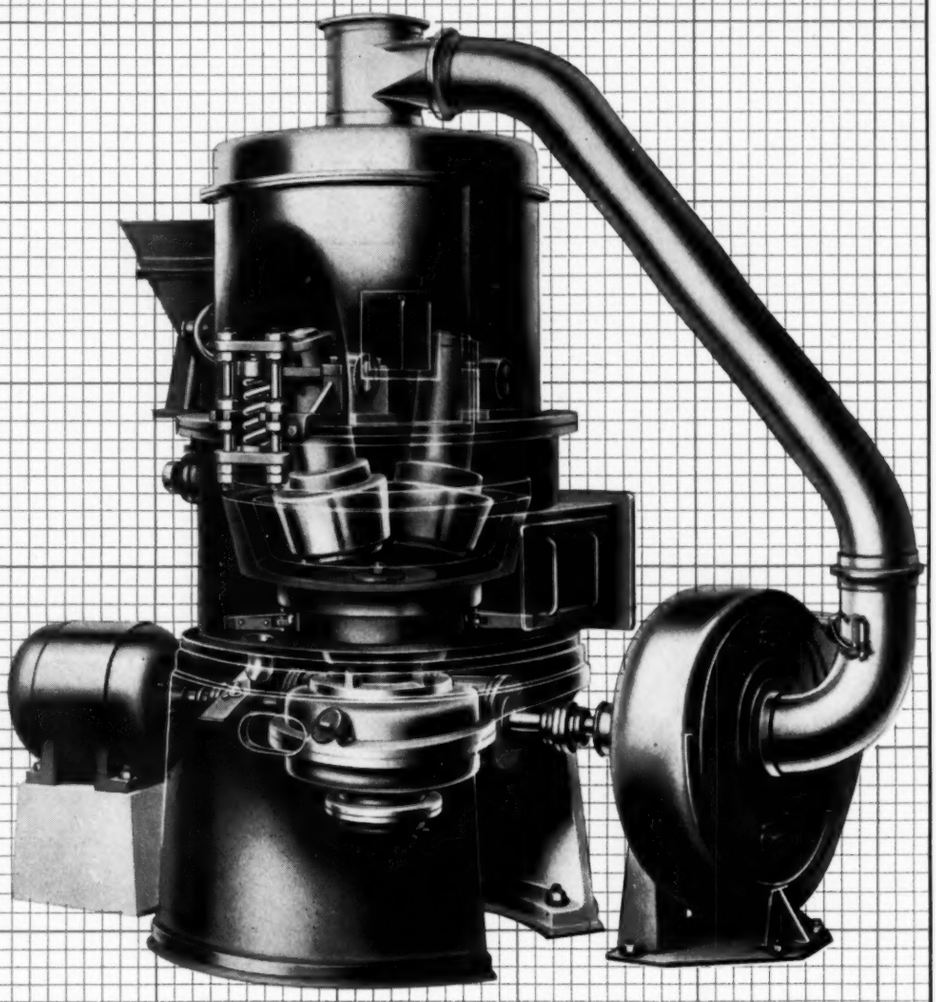

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME ELEVEN NUMBER ELEVEN

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Combustion is published monthly by Combustion Publishing Company, Inc., a subsidiary of Combustion Engineering Company, Inc., 200 Madison Avenue, New York. Frederic A. Schaff, President; Charles McDonough, Vice-President; H. H. Berry, Secretary and Treasurer. It is sent gratis to consulting and designing engineers and those in charge of steam plants from 500 rated boiler horsepower up. To others the subscription rate, including postage, is $2 in the United States, $2.50 in Canada and Great Britain and $3 in other countries. Single copies: 25 cents. Copyright, 1940 by Combustion Publishing Company, Inc. Printed in U. S. A. Publication office, 200 Madison Avenue, New York. Issued the middle of the month of publication.

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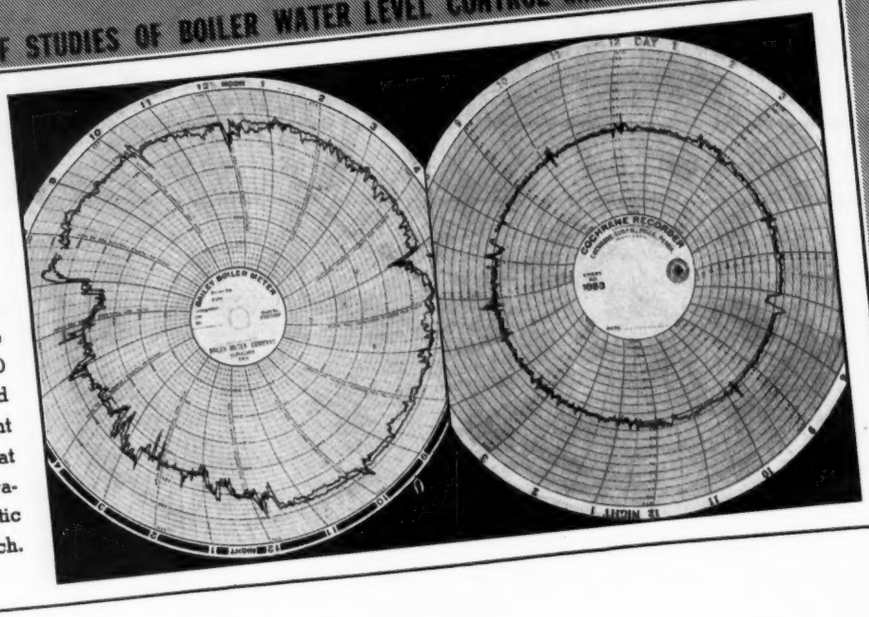

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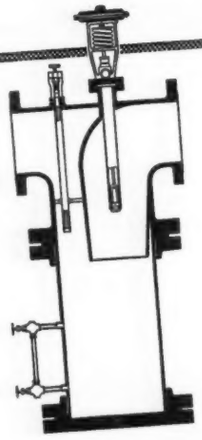

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EDITORIAL

Industrial Steam Conditions Discussed

The paper by W. F. Ryan on "Progress of Higher Pressures in the Industrial Plant," at the Worcester Meeting of the A.S.M.E., was useful not only in presenting an analysis of steam conditions in eighty-five modern industrial power plants, aggregating over thirty million pounds of steam per hour and more than a million kilowatts capacity, but the extensive discussion which it elicited afforded a representative cross-section of opinion among industrial power engineers.

Excluding a few very large installations, more or less comparable with central stations, as well as some serving certain special processes, it appeared to be the consensus that pressures of four hundred and fifty to seven hundred pounds and steam temperatures not exceeding seven hundred and fifty degrees are the most desirable for the majority of installations supplying both power and process steam; and that it is well to proceed with caution in choosing higher temperatures. Within this conservative range, high availabilities and excellent performance were reported.

Where higher pressures and temperatures are under consideration the extra investment in piping, valves and superheaters may go far toward offsetting thermal gains and, as one discussor pointed out, high steam temperatures are likely to involve furnace temperatures productive of slagging with certain coals when operating at high ratings. To combat such slagging, soot-blowing equipment and extra manual labor become necessary and the possibility of outage is increased. Since the general trend is toward minimum reserve capacity, and in some cases no reserve, availability is of paramount importance.

While the character of the material in process and the ratio of power to process demands are usually determining factors in the selection of steam conditions, it was observed that in some industries, because of refinements in process, the power load has increased faster than the steam load—a matter warranting consideration with reference to the probable useful life of the power equipment. In other cases, the existence of expensive process equipment designed for lower pressures may govern the selection, despite a more favorable heat balance offered by higher pressure.

It is generally conceded that the proper design of an industrial power plant may present a more complex problem than that of a central station. Steam utilization and power demand must be viewed jointly with the objective of attaining the lowest overall manufacturing cost. These considerations will often be found to transcend apparent thermal gains.

An abstract of Mr. Ryan's paper, together with high spots of the discussion, appear elsewhere in this issue and the opinions offered warrant full consideration by those responsible for the design and operation of industrial power plants.

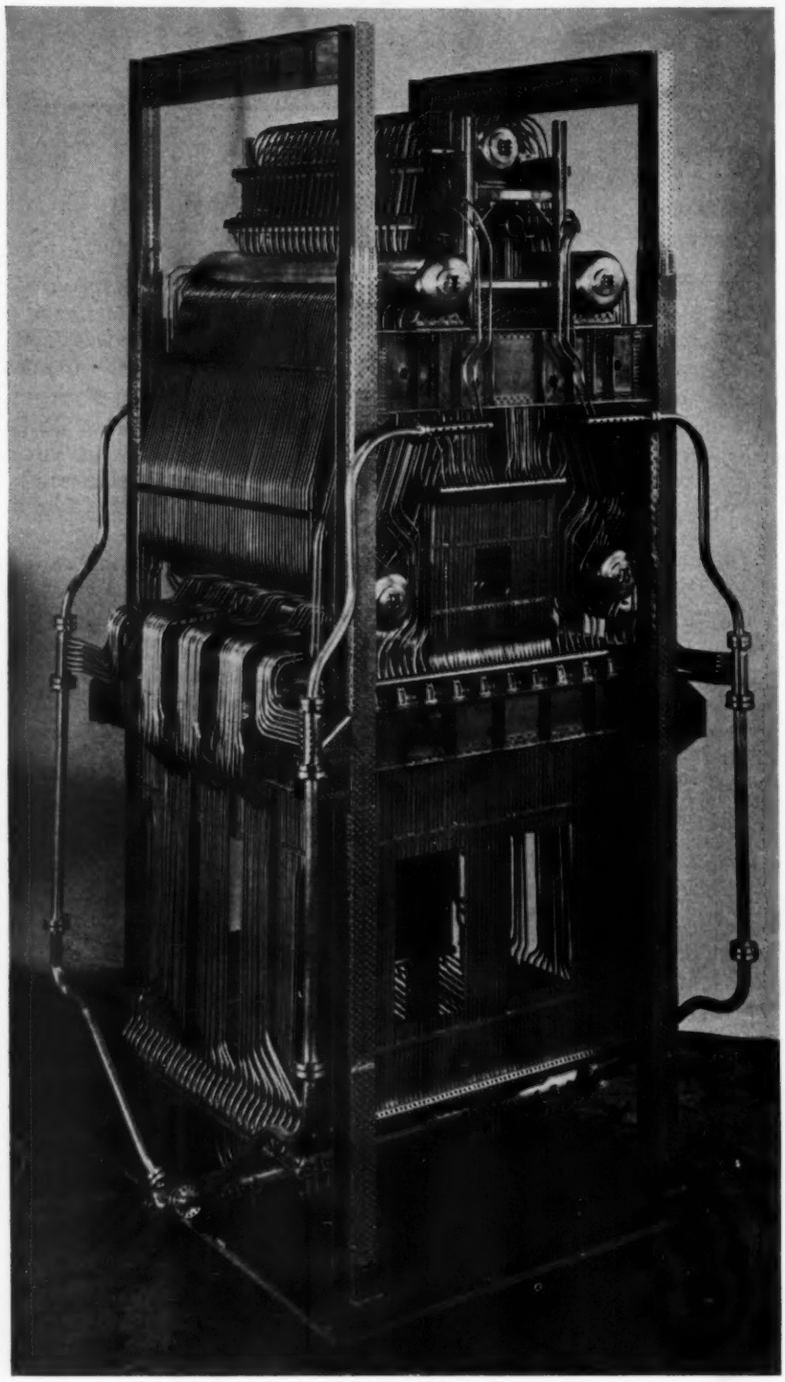
New Coal Prices Versus Competitive Fuel

Examiners of the Bituminous Coal Division of the Interior Department have finished their work and have filed the recommended minimum prices with the Director of that Division. The latter has now released them for public inspection and for the filing of exceptions before making them effective in final form. It is reported that, although these prices represent increases over present mine prices for many coals, they are lower than present quotations in some instances. The minimum average price of $2.072 per ton at the mines, under the recommended prices, is said to be approximately eleven cents a ton greater than that received by the industry in 1937, the most recent period for which figures are available. The prices range from a low of ten cents per ton for a very inferior grade of coal dust produced as a by-product from certain mines in the Middle West up to as high as $4.80 per ton for a fine grade domestic lump.

It will undoubtedly take some time for readjustment of the markets and for a study of the new prices to reveal their full import with reference to coal purchasing for the individual plant. Some informative sources offer the opinion that the differentials are such as to promote wider use of the better coals in many instances and lesser movement of the poorer grades, while others prophesy the ultimate collapse of the price structure on the assumption that it will prove unworkable. Only time will afford the answer and demonstrate whether the vast amount of effort and the huge expenditure involved will have been in vain.

Over many years prices of coal and oil have been maintained on a more or less competitive basis, with one or the other showing marked advantages during brief periods, due to abnormal conditions within these respective industries. At present, however, with an oil shortage in certain localities, higher prevailing fuel oil prices and new refining processes, making it possible for the refiner to control and direct the products from the crude into the most profitable channels, it is unlikely that fuel oil will assume an immediate competitive position with coal, despite some advance in price of the latter. How long this situation may prevail will most likely depend upon many unforeseen factors, both foreign and domestic.

The present trend of making provision for burning either pulverized coal or oil in the large and medium-size furnaces of new installations, as an insurance for the future, is likely to continue, as will also the employment of stokers under smaller units. It is probable, however, that many existing plants will find it advisable to install modern fuel burning equipment to compensate for such advances as may develop in the new levels of coal prices.



Scale model of latest million-pound per hour, 1400-lb pressure steam generating unit at the Rouge Power Plant of the Ford Motor Company which is being shown in Combustion Engineering Company's space at the New York World's Fair. The model, built by E. C. Keithley, service engineer of the latter company, is made of aluminum, stands nearly 6 ft high, contains ¾ mile of boiler tubing, 2800 ft of superheater tubing, 11,040 slip spacers welded to the superheater elements, and required the placing of over 14,000 rivets in the framing. All tubes are rolled into the drums and headers. Approximately 3000 man-hours were required in its construction.

GRINDABILITY INDEX

Determination by the Ball-Mill Method

The author shows how the Ball-Mill Method for determining grindability indexes may be materially shortened with no significant sacrifice in accuracy. He discusses the relationship of both friability and volatile matter to grindability. A curve shows an approximate comparison between the index numbers of both the Hardgrove and Ball-Mill Methods, and a table gives the Ball-Mill Grindability Index Values of 130 coals.

By H. L. BRUNJES, Fuel Technologist,
Fuel Engineering Co. of New York

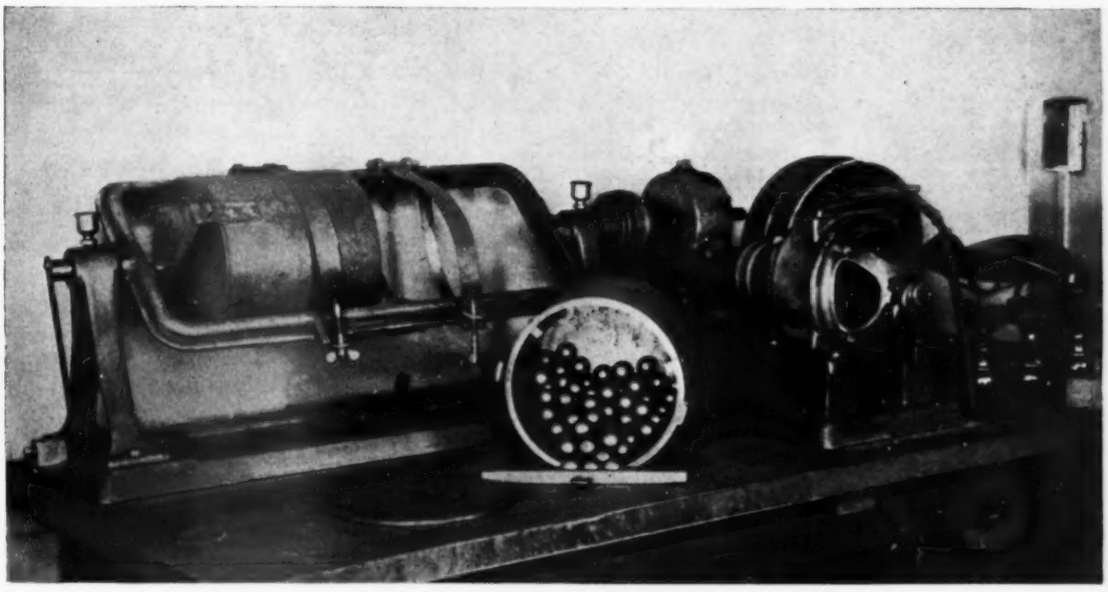


Fig. 1—Typical Ball Mill

WHILE coal has been burned in pulverized form for a long time, it has only been within the past ten or fifteen years that attempts were made in the laboratory to determine its resistance to pulverization or, as it is now called, its relative grindability. The word "grindability" which we are using is a suitable description of what appears to be a composite of a number of various characteristics of coal, among them crushing strength, toughness and hardness or resistance to abrasion. All of these contribute something to the property described by this serviceable and inclusive term. It was known that coals varied widely in these respects, some requiring three or four times more energy or work to reduce them to the proper degree of fineness than others of a type that is softer or easier to grind.

As the art of burning pulverized coal developed, it was soon found necessary to measure this quality in a manner more convenient than the burdensome large-scale plant test under actual operating conditions, and to determine an index by which coals could be ranked relative to one another and by which their behavior, under certain pulverizing conditions, could be predicted. The development of such an index was coincidental with, or followed closely, the rapid rise in the use of coal in pulverized form around 1920.

Of the earlier investigators, Cross (1) in 1926 proposed such a method, together with an index of rating. This was followed by Gould (2) in 1930, and Hardgrove (3) in 1931. Shortly after, several others appeared, among them Baltzer and Hudson (4) in 1933 and Yancey, Furse and Blackburn (5) in 1934. In the latter year, the A.S.T.M. Sub-Committee on Pulverizing Characteristics of Coal of Committee D-5, sponsored a series of cooperative tests among various laboratories, for the

purpose of selecting, from among the various proposed procedures, those suitable for inclusion in the A.S.T.M. standards. The methods selected for this were the Bureau of Mines Ball-Mill Method of Yancey, the Cross Method, the F.R.L. Method of Baltzer and Hudson, and the Hardgrove Machine Method. The results of these cooperative tests were published by the Bureau of Mines (6). After careful consideration, it was decided to advance two of these methods to the status of Tentative Standards. These were the Bureau of Mines Ball-Mill and the Hardgrove Machine Methods.

Since 1935, when these standards were adopted, a rather comprehensive survey has been made of the grindability indexes of various coals by both procedures. In our work, using the Ball-Mill Method, we have determined the index figures for several hundred coals representing practically every important producing district in the Appalachian fields. Some hundred or more are given in Table 1. These were selected to give as complete a picture as possible of all the principal fields and beds and also to give the ranges likely to be encountered when such information was indicated by a series of determinations. Ball-Mill grindabilities on some American coals were also made by Bureau of Mines, North West Experimental Station in 1938 (7).

For a survey of the Alabama fields, reference should be made to a Bureau of Mines report issued in 1938 (8).

Examination of the data will indicate that, except for a somewhat close relationship between coals mined in the same seam within generally small producing areas, there does not appear to be any quite definite correlation between this grindability characteristic and any other commonly applied tests to coal that could be used for anything more than a very general guide for predicting the grindability.

TABLE 1—BALL-MILL GRINDABILITY INDEX VALUES OF COALS FROM MINES IN COUNTIES INDICATED

Seam	County	Index Values
	Pennsylvania	
Lower Kittanning	Cambria	96-94-93-91-76-75
	Armstrong	51
	Center	82
	Clearfield	83
	Clarion	55-50-49-44
	Elk	51-49
	Fayette	80
	Indiana	93
	Jefferson	76-74-55-52
	Somerset	94-91
Upper Kittanning	Somerset	90-89-86-85
Lower Freeport	Cambria	80-84-83-83
	Clearfield	68
	Jefferson	73-70-59-58
Upper Freeport	Armstrong	58-51-46
	Cambria	87-86-83-79-77-73
	Clarion	53
	Indiana	73
	Westmoreland	53
Thick Freeport	Allegheny	52-48
Pittsburgh	Allegheny	51-51
	Fayette	65-51
	Westmoreland	70-54-53-51-48
	Washington	53-49-47-38
Bloss & Seymour	Tioga	92-89-86-79
Anthracite	Northumberland	37
	Schuylkill	33-25-30
	West Virginia	
Kittanning	Randolph	61
Upper Freeport	Preston	61
	Tucker	79
Pittsburgh	Brooke	49-49
	Harrison	50-44
	Marion	54-54-51-49-48-48-47
	Monongalia	59-59-58-57-56-56-55-51-50-49-48
Redstone	Upshur	49
Sewickley	Monongalia	48
Sewell	Greenbriar	79-73-71
	Fayette	74-74-73
	Raleigh	94-90-84-84-82
	Randolph	69-55-51
	Webster	58
Beckley	Raleigh	85
Fire Creek	Fayette	86
Pocahontas No. 3	McDowell	84-79-79
Welch	McDowell	86-84
No. 5 Block	Clay	44
	Virginia	
Bull Creek	Buchanan	65-62-60
Upper Banner	Dickinson	64
Taggert	Wise	45
	Kentucky	
Elkhorn	Floyd	40-37
High Splint	Harlan	37-34

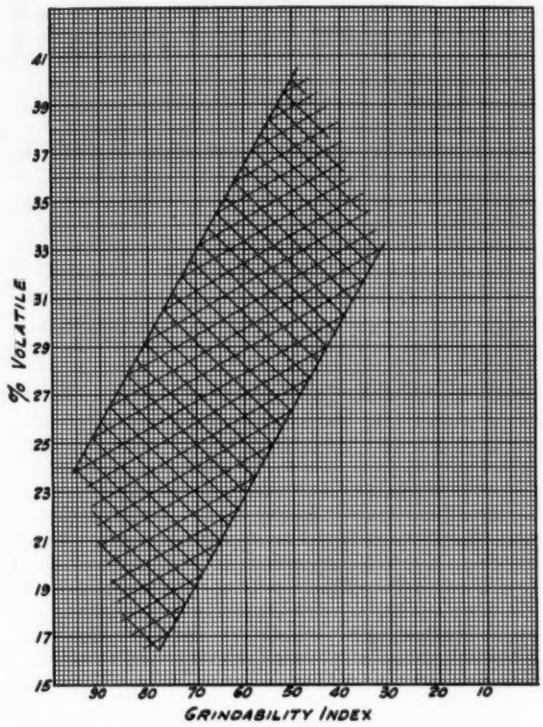


Fig. 2—Variation of grindability with volatile

The general trend of the upper limits of volatile vs. grindability indicates a straight line; but among the coals tested no points fell in the range 60–73 grindability where volatile was 32 per cent or more.

To some extent, grindability will follow the volatile content, but inversely, that is, the higher the volatile the lower the grindability index. This will be found to be very general, however, when noting the width of the band covering the comparisons given in Fig. 2. It will be noted that within any given percentage of volatile the grindability may vary as much as 25, although in no case have we found coals having 32 per cent or more volatile exceeding a grindability index of 60.

It might be said, further, that the widest spread in the grindability volatile ratio is between 26 and 32 per cent volatile. Even though this comparison is rather wide, it is significant as per cent of volatile is an important feature in selection of coal for pulverized burning. If we think of burning coal in this form as an attempt to simulate the burning of a gas or an atomized oil with its flexibility of manipulation, it would follow that the more of the coal substance that would burn as a gas, the closer the approach to this ideal condition. Volatile definitely affects flame propagation and maintenance of ignition.

In the measure of the friability, an apparently closely allied characteristic, nothing more than a very general comparison can be made. In Fig. 3, there is given the comparison of these two properties. Again there is indicated a rather broad or general correlation. In fact, the relationship is somewhat less definite than that of the volatile. Probably it can only be said that the coals having a low friability index will also have a low grind-

ability index. Actually, the relation is apt to be somewhat better in a practical way when grindability values are predicted in the slack sizes when judged by the ratio of hard structure sized coals to small slack shipped from any given area. It should be borne in mind, however, when making comparisons such as this, that friability is really a measure of the strength or tenacity by which the lump of coal is held together, while the grindability test is performed on the smaller particles that go to make up this lump.

It is important, however, to bear in mind both of these relationships, even though they are, at the best, very general, for they have a rather definite place in the economics of selecting coal for pulverizer use. In those areas producing high volatile, hard structure, sized coal, it will be found that the slack or pulverizer size is in the harder-to-grind classification. Conversely, those districts or areas shipping but little sized coal and where nut-slack or slack accounts for some 80 per cent of the total tonnage, the grinding indexes are to be found in the

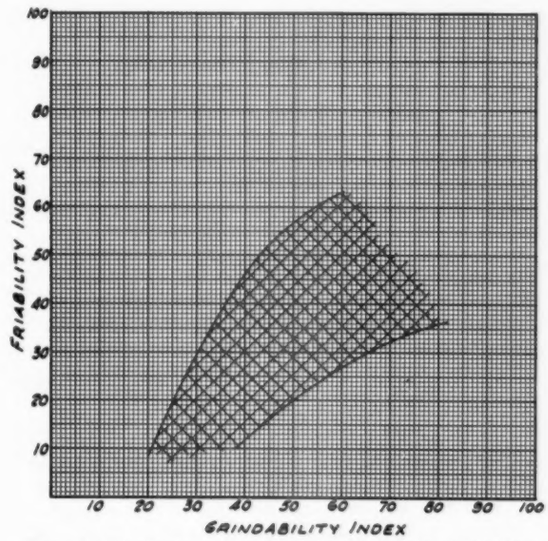


Fig. 3—Variation of grindability with friability

higher range. These factors have a pronounced effect on the market values of the pulverizer slacks, for mines, producing a preponderance of sized coal that normally brings the higher price, can afford to offer the slack at a sacrifice to insure free movement of the more profitable product, while the operator producing more friable coal will naturally have to realize higher prices on the smaller sizes which constitute 60 to 80 per cent of his production. As these relatively wide values generally exist in the coal market, the consumer will naturally be interested in the lower cost product. It is here that the determination of the grinding characteristics intrude on the problem of coal selection. While there may be other factors involved in selecting coal for pulverizer use, the grindability directly affects the mill capacity, hence becoming a possible limitation.

Among the earlier installations of pulverizing equipment, particularly along the Eastern seaboard, where a variety of coals having rather widely differing characteristics are available, the mill capacities were very often predicated on the use of a very soft, or easy-to-grind coal. It was soon found that this became a somewhat serious limitation and imposed certain penalties on the buyer, who could only draw from those fields where the slack sizes were necessarily in the higher price brackets. For such a consumer, it was almost imperative that he have grindability values available, which he could translate into terms applicable to his plant performance. For, unless such information was available, trials might easily have proved both unsatisfactory and costly.

While Frisch and Foster, in their paper on pulverizer performance (9), have demonstrated that a grindability index figure, or the range between such figures, does not necessarily denote the same action in all types of pulverizing equipment, they point out, however, that once the characteristics of the particular pulverizer are determined by using coals of different grindability values, the performance of other coals can be predicted from their index rating. Used in this manner, the grindability index becomes a useful measure to the coal buyer. To some extent it has also been used in establishing the values of coal under the price fixing features of the Bituminous Coal Act.

Between the two grindability indexes in common use (the Ball-Mill and the Hardgrove), there is available a scale of comparable values, although the basis for each is somewhat different. In the Ball-Mill procedure, the index figure 100 signifies the softest or most easily ground coal found to date. This was established after a wide investigation of all types and kinds of coal from every important producing field or area in the United States and abroad. The index 100 on the Hardgrove scale does not mean the softest or most easily ground coal, but simply is a standard reference point, based on the figures given when using a particular coal designated as "standard." On the Hardgrove scale, it should be found possible to obtain index figures as high as 118, to be comparable with 100 in the Ball-Mill Method index. In Fig. 4 is given a means of comparing the values on both these scales with a fair degree of accuracy. While the scale has only been definitely proved throughout a rather

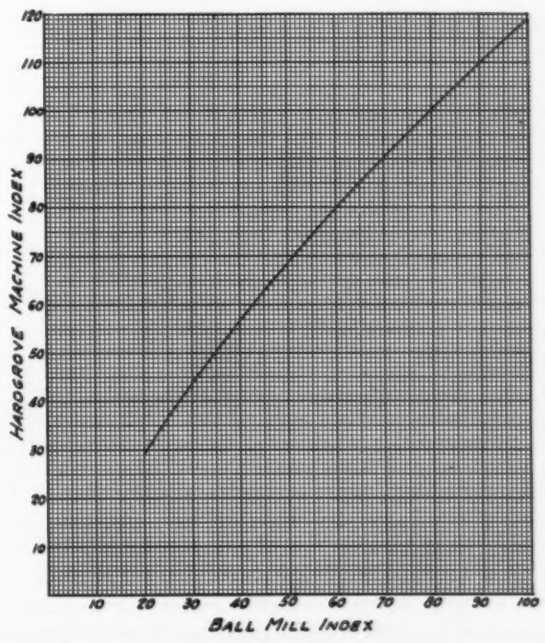


Fig. 4—Relation between Ball-Mill and Hardgrove indexes

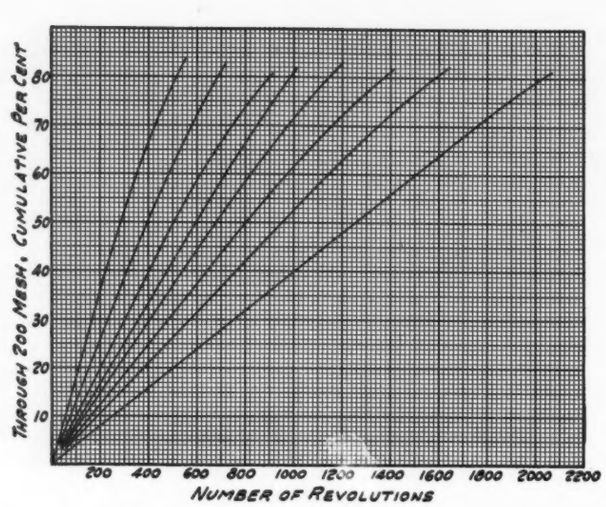


Fig. 5—Per cent through 200 mesh vs. revolutions of Ball Mill

narrow range, it is, for all ordinary purposes, reasonably reliable.

That these two methods should be comparable to this degree is rather surprising, as their means of determining this characteristic are rather divergent. In the Hardgrove Machine Method (10) a relatively small amount of coal is subjected to a short period of grinding in a machine that might be termed a miniature of an industrial type pulverizer, while in the Ball-Mill Method (11) coal is subjected to a continued grinding action to a certain state of fineness. The measure of work involved in doing this becomes the measure of grindability. During the grinding action, in the latter method, the finely pulverized material is removed at regular intervals to simulate, to some degree, the scavenging action of the air-swept mill.

Briefly, the Ball-Mill Method may be described as employing a tube or tumbler mill containing a charge of steel balls, Fig. 1. A 500 gram sample of the coal, sized between 10 and 200 mesh, is revolved in this mill containing one hundred 1 inch steel balls, until approximately ten per cent of the sample will pass a 200 mesh sieve. This is called a cycle. After each cycle, this minus 200 material is removed and discarded; the remainder is again subjected to another cycle of the same number of revolutions and the removal of the minus 200 material is repeated. This cyclic grinding is continued in this manner until 80 per cent of the material, or 400 grams, is removed as passing 200 mesh. The revolutions required to do this is the measure of grindability. As 500 revolutions was found to designate 100, or the most easy to grind coal in the index, the formula for converting the revolutions into grindability becomes 50,000 divided by the number of revolutions.

In our investigation of the Ball-Mill procedure, we found that the number of cycles (12) could be reduced to four, or until 40 per cent of the material passed the number 200 sieve, and from this there could be calculated the grindability index with no significant sacrifice of accuracy. This greatly shortened the time necessary for the determination of the grindability index. For many purposes, where only a rough estimation is required, it might even be shortened further, although in shortening the method to two cycles of grinding, there is a tendency for results to become somewhat erratic in certain ranges of the scale. In Fig. 5, there is given a number of grinding curves for typical coals in each range. One will note in this the progressive formation of minus 200 material and the relationship that exists between the various cumulative percentage points and the 80 per cent index value. It will be found possible to derive a formula relating these points, although if this is done below the 30 per cent point, the results are apt to be found to vary rather widely on different types of coal.

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Combustion Engineering Company Officers

At the annual organization meeting of Combustion Engineering Company, Inc., Joseph V. Santry was elected President to succeed Frederic A. Schaff who becomes Vice Chairman of the Board. George L. Bourne was re-elected Chairman of the Board. Mr. Bourne is also Chairman of the company's parent organization, The Superheater Company, of which Mr. Schaff is President.

Mr. Santry, who has been Executive Vice President since 1933, became identified with Combustion Engineering shortly after its organization in 1914 and was elected a Vice President in 1918. He attended Massachusetts Institute of Technology and was first employed by the Boston Elevated Railway Company, of which company he subsequently became Assistant to the Superintendent of Power Stations. Later he organized and became President of the Schumaker-Santry Company of Boston, representatives of Combustion Engineering and other prominent manufacturers of power plant equipment in the New England territory. He is widely known throughout the power industry and is a member of the American Society of Mechanical Engineers and the Engineers Clubs of New York and Boston.

Martens H. Isenberg, who has been Vice President in Charge of Production, was elected Executive Vice President of Combustion Engineering Company to succeed Mr. Santry.

Albert C. Weigel, formerly Assistant to the President, was elected a Vice President, and the following were re-elected Vice Presidents: Harold H. Berry, John Van Brunt, F. H. Rosencrants, Charles H. True and John S. Skelly. Other officers re-elected are: Harold H. Berry, Treasurer, George D. Ellis, Secretary and Controller.

The following re-appointments were made: I. B. Swigart, Assistant Secretary and Assistant Treasurer, Thomas F. Morris, Assistant Secretary. Frank R. Fitzpatrick was appointed Assistant to the Vice Chairman.

Higher Pressures in Industrial Plants

By WILLIAM F. RYAN

Mechanical Engineer,
Stone & Webster Eng'r'g. Corp.

Excerpts from a paper presented at the A.S.M.E. Spring Meeting at Worcester, Mass., May 1 to 3, 1940. The complete paper will appear in the June issue of "Mechanical Engineering." The author surveys the pressures, temperatures, steam generating equipment, prime movers and costs in 85 industrial power plants employing steam pressures of 500 lb and over and arrives at certain deductions therefrom. High spots of the discussion are appended.

HIGH pressure is a relative term and for the purpose of this paper is defined as not less than 500 lb per sq in. at the prime-mover throttle. Under this definition, the first high-pressure industrial power plant went into operation at the Solvay Process Co., Syracuse, N. Y., in 1927, although another manufacturer, The Masonite Corp., Laurel, Miss., had installed a 1250-lb per sq in. boiler for purely process work in 1926. No high-pressure industrial plants were reported in 1928, and not more than 12 were in operation at the end of 1933. Later development has been more rapid, but published records and other sources of information disclose only 85 plants now operating in the United States supplying power and steam to industries, in which the throttle pressure is 500 lb per sq in. or higher. This number includes six installations owned and operated by public utilities. The 85 plants have a combined power generating capacity of 1,166,875 kw, a total steam generating capacity of 30,785,300 lb per hr, and represent a probable investment of at least $125,000,000. A number of additional plants are now under construction and it is expected that by the end of this year there will be nearly 100 such plants in operation with a combined generating capacity of approximately 1,350,000 kw.

These totals do not include plants, at least 40 in number, where high-pressure boilers are installed to supply steam for process use only, for testing equipment, or for future power generation, nor do they include those in which the boilers are designed for 500 to 600 lb per sq in., but which actually supply steam to prime movers at 425 to 475 lb per sq in.

The foregoing figures include the River Rouge power plant of the Ford Motor Company, which contains one 15,000-kw back-pressure turbine-generator supplying steam to the manufacturing plant, and three 110,000-kw high-pressure condensing units which differ in no way from typical central-station machines. In subsequent analyses, however, these three condensing units are excluded from the totals in order to prevent distortion of the averages.

Pressures

Excluding the condensing units at River Rouge the plants mentioned contain 134 turbine-generators and two reciprocating-engine generators. Table 1 shows the number and capacity of units for various pressure ranges.

TABLE 1

Throttle pressure Lb per Sq In.	No. of Prime Movers	Combined Capacity, Kw
500–599	21	78,525
600–749	87	439,400
750–899	14	86,500
900–1199	0	0
1200–1600	11	209,450
Over 1600	3	23,000
	136	836,875

There is no "trend" of pressure with respect to time. The highest pressure installation included in this group, that at the Diamond Alkali Company, Painesville, Ohio, with a throttle pressure of 2000 lb per sq in. started operation in 1939, but the only other plant operating at a pressure above 1600 lb per sq in. dates from 1931. This is at The Philip Carey Mfg. Co., Lockland, Ohio, with a throttle pressure of 1650 lb per sq in.

No generalizations can be made as to the best pressure for plants supplying industrial steam. For condensing turbines in utility plants, it may well be argued that in localities affording moderately priced fuel and abundant circulating water, there is no profit in throttle pressures above 900 lb per sq in.[1] In the industrial plant, however, it may be economical to use the highest pressures commercially available if the electric power demand is high in proportion to the steam required for process, and if load factor and other conditions are favorable.

In many industrial-plant designs, the question of pressure has been approached from the wrong angle. In order to generate more by-product power in a given situation, process pressures have been limited or even reduced when greater overall savings might have been made by exactly the opposite procedure.[2] In some heat applications, particularly evaporative processes, high saturated-steam temperature is quite as valuable as it is for power generation.

Temperature

Table 2 shows the number of units and capacity included in different ranges of throttle temperature.

[1] "Why Exceed 100 Lb per Sq In.," by A. L. Mellanby, *Power and Works Engineer*, vol. 33, no. 379, January 1938, pp. 5–7.

[2] See discussion by Z. G. Deutsch, *Trans.* A.S.M.E., vol. 53, 1931, paper FSP-53-26a, p. 350.

More than half of the units having 42 per cent of the total capacity operate at temperatures below 750 F and, in general, the tendency has been to use the lowest temperature that would give the required quality of exhaust steam. Nevertheless, the author believes that the problem of temperature in industrial power applications has not been correctly approached in many cases, and that some of the existing installations might have achieved equal results at less cost by using lower pressure and higher temperature.

The effect of throttle temperature on the water rate of back-pressure turbines is sufficiently well understood. For example, with 100 lb per sq in. back pressure, as much by-product power per unit of process steam can be generated with 550 lb per sq in. and 750 F at the throttle as with 700 lb per sq in. and 675 F. The lower-pressure, higher-temperature steam, however, has a higher enthalpy, and it has been incorrectly assumed that a plant designed for those conditions would necessarily consume more fuel per unit of output. Also, the exhaust from the prime mover would be highly superheated and in many processes superheat is of no value. However, if a thoroughfare desuperheating heater is installed in the exhaust to remove the surplus superheat and transmit it to the boiler feedwater, the fuel consumptions for the two steam conditions would be identical, but the lower-pressure installation should show an appreciably lower capital cost, and slightly lower expense for auxiliary power, maintenance and perhaps for feedwater treatment.

TABLE 2

Throttle Temp, F	Number Units	Combined Capacity, Kw
Under 600	1	10,000
600–649	6	12,250
650–699	8	31,000
700–749	57	310,775
750–799	47	211,100
800–849	9	71,000
850–899	0	0
900 and over	8	190,750
	136	836,875

Prime-Mover Characteristics

Seventy-three per cent of the units included in this survey are back-pressure machines. The remaining 27 per cent, having 38 per cent of the total capacity, are equipped with condensers. These condensers are usually small, in some instances designed for less than 15 per cent of the maximum throttle flow.

Of the condensing machines, only one 500-kw unit is nonextraction. The latter, however, operates in parallel with a larger machine exhausting at 40 lb per sq in. and the two units in this plant are, therefore, the equivalent of a condensing extraction machine. One large unit now under construction, which may operate at a pressure of 500 lb per sq in. or more, is a straight condensing machine with extraction only for feedwater heating.

Extraction pressures range from 5 to 400 lb per sq in.; 38 turbines are arranged for single extraction, 15 for extraction at two pressures, and one is a mixed-pressure dual-extraction machine. The available information does not disclose any machines with more than two fixed-pressure extraction connections, or any back-pressure machines which have two. In some plants, however, high-back-pressure units top lower-pressure extraction machines not included in the scope of this survey, and some high-pressure machines in the same plant are designed for extraction or exhaust at different pressures so that by-product power is generated at several different levels.

In 1925 there was some reason for expecting that many of the smaller high-pressure industrial power developments might utilize reciprocating engines for prime movers. This expectation has not been realized due principally to the present high efficiency and reliability of back-pressure turbines, even in relatively small sizes. The engine-generator installation at Lockland, Ohio, has been in successful operation for several years, using steam at 1650 lb per sq in. and 810 F, and there is no mechanical reason why steam engines could not be used with very high steam pressure and temperature. However, the water rate of these engines is no better than the water rate of a present-day noncondensing turbine of the same size and the radiation losses are appreciably higher; also more frequent and more extensive outages are required for inspection and maintenance.

Steam Generating Equipment

Many of the high-pressure installations designed between 1928 and 1933 followed the more conservative design of earlier low-pressure boilers but all of the more recent installations for which data are available have rates of heat transfer which would have been considered excessive 15 years ago, although they are lower than current central-station practice. Sixteen recently installed industrial boilers, operating at 600 to 850 lb per sq in. pressure and ranging in capacity from 65,000 to 500,000 lb per hr show a weighted average heat input of 9200 Btu per sq ft of total surface, including boilers, waterwalls and economizers. The corresponding figure is 16,000 Btu per sq ft for six utility-plant boilers, operating in the same pressure range, with individual capacities of 140,000 to 575,000 lb per hr, but with the same total capacity as the sixteen industrial boilers. The lower average rate of heat input for the industrial boilers is due chiefly to the general use of treated water for boiler feed, and the higher concentration of solids in the circulating system.

Tremendous progress has been made in the art of boiler feedwater purification, but it is still the major problem for high-pressure industrial work where condensate is not returned from the process. The highest pressure boiler in the group is fed with treated water, but ten of the twelve plants operating at pressures above 1200 lb per sq in. use condensate, exclusively. The energy loss which results from the use of evaporative condensers is less than is commonly supposed, and the cost of evaporators is partly offset by savings in cost of steam generating equipment, due to the possibility of using less heating surface and smaller drums, when pure feedwater can be assured.

Reserve Capacity

One of the outstanding features of recent industrial-plant design is the willingness of the owners to rest factory production wholly or partially on a single boiler or turbine unit. For low-pressure plants of the type prevalent in 1925, it was axiomatic that there must be a sufficient number of boilers so that one could be out of service for inspection or repairs at any time without curtailing production. There are relatively few of the modern high-pressure installations where this reserve capacity has been provided, but the results have been reasonably satis-

factory. Of the 85 plants included in this survey, 29 have a single high-pressure boiler, although in some cases, older low-pressure boilers relay the high-pressure equipment.

Costs

Construction costs vary widely and the cost of any single installation has little significance because of the extreme differences in conditions. The weighted average costs for 13 installations ranging in capacity from 2000 to 100,000 kw and with pressures from 600 to 850 lb pressure is approximately $2 per lb per hr of steam generating capacity plus $60 per kw of electric generating capacity. This formula, however, applied to any individual installation, may be in error by as much as 35 per cent, and the fact that some were built during low-construction-cost periods makes them unreliable for present-day use. Steam-generating capacity should not be confused with net delivery to process mains, and it should be remembered that the large ratio of steam generation to power output results in an auxiliary power consumption which appears high when compared with central stations. On a net-output basis, the average cost for the foregoing plants would be approximately $2.50 per lb of steam per hour plus $72 per kw. For individual plants the steam factor ranges from $1.48 to $3.57 per lb and the electric factor from $38 to $123 per net kw.

Available figures on production expense are even more unsatisfactory for comparative purposes than the installation cost data, due to variations in operating conditions and bookkeeping methods. The best statement which the author is able to make, based on the limited data available, is that in moderate-sized plants operating at a good load factor the production cost of 1000 lb of steam and 30 kwhr from fuel, costing 15 cents per million Btu, ranges from 29 cents to nearly 40 cents. This is bare operating expense, exclusive of depreciation, taxes, or interest on investment, and the units are net deliveries to manufacturing departments, not gross generation. How these costs are divided between steam and power is a matter of bookkeeper's choice.

Discussion

The wide interest in the subject of Mr. Ryan's paper was manifest by the extensive discussion which it brought out. Abstracts of a number of these discussions follow:

H. D. Harkins, Mechanical Engineer of E. I. du Pont de Nemours & Co., said that experience of his company with several plants employing 400 and 600 lb pressure indicates no material difference in operating problems as between these two pressures. The use of higher steam pressures for process has made no great progress in the numerous plants of that company, despite the fact that 1200 lb is used in a few instances for certain processes. In these cases small quantities of steam are required and the high pressure is furnished by steam compressors rather than by boilers. The trend seems to be toward higher boiling-point organic compounds in preference to high-pressure steam. The company has continued to install engine-driven air and ammonia compressors in sizes up to 750 hp to operate at 400 lb steam pressure.

Mr. Harkins agreed that boiler feedwater is still a major problem in high-pressure industrial plant operation and was inclined to regard the return of condensate from process with suspicion. He recommended that such return lines be equipped with conductivity meters and suitable alarms. He also ventured the prediction that, because of the higher first cost and lower efficiency measured by the net kilowatt-hours produced, the evaporator cycle would give way to further progress in water treatment within the next five years.

F. H. Cronin, Chief Engineer of the National Vulcanized Fibre Company, observed that the maximum permissible temperature is limited by the character of the material in process, and that the usual operating pressures in the paper and vulcanized fibre field are fixed by the fact that drying and other processing equipment is generally designed for low pressures. Furthermore, such equipment has a long life and is expensive to replace. He believed that there are many opportunities of effecting savings by the installation of back-pressure plants, even in relatively small capacities.

Referring to a small plant in the field of paper and vulcanized fibre, with which he has been associated, Mr. Cronin cited the savings that had been effected over the last 4½ years through the installation of two boilers and turbines operating at 600 lb, 700 F to replace a 125-lb steam plant and purchased power. There is installed a 1000-kva back-pressure turbine with extraction at 125 lb and a 500-kva combined bleeder and condensing unit, bleeding at 40 lb up to full load and running condensing up to two-thirds capacity. The larger machine is under back-pressure control and the smaller unit maintains the frequency. Either of the two boilers is capable of carrying the plant load, and the makeup runs from 50 to 75 per cent.

With an average boiler efficiency last year of 81.5 per cent and a fuel cost of 17.7 cents per million Btu, the cost per 1000 lb of steam and 23.04 kwhr was 31.7 cents, electricity being produced at well under 5000 Btu per kwhr. With an investment of $230,000 the savings during the last 4½ yr, over the old plant operation, have ranged from $39,000 to $55,000 per year.

W. F. Sibler, Supervisor of Power for the West Virginia Pulp and Paper Company, stated that by the end of this year every one of his company's six mills will be operating at 600 lb pressure, although the steam temperatures have been limited to 720 F, which temperature is limited by process requirements. He expressed the opinion that, although there may be useful applications for higher pressures and also for thoroughfare desuperheaters, it would be well to proceed cautiously in this direction. When operating costs, particularly maintenance and repairs, as well as outage, are considered, conservative design, while perhaps entailing greater first cost, pays good dividends in the end. High availability is a direct result of design, and it bears emphasizing that reduction in installation cost should not be brought to a point where reliability is jeopardized. The advisability of designing a plant to burn the greatest variety of fuel available in the district was attested by the coal strike last year.

As to allocation of costs between power and process steam, Mr. Sibler suggested that the former should be charged with the heat absorbed by the turbine plus that going to the condenser, properly corrected for boiler efficiency and auxiliary losses; also, that it carry all the fixed charges resulting from investment in the high-

pressure steam and power plant, over that of a low-pressure steam plant sufficient to supply the necessary process steam. The cost of the heat used for power production should be figured as to its portion of the total heat used for power and process.

H. W. Johnson, Assistant Chief Engineer of the Celluloid Corporation, Newark, N. J., described the 600-lb, 650 F topping installation made by that company in 1937. This consists of two 55,000-lb per hr pulverized-coal-fired steam-generating units, a back-pressure turbine exhausting at 150 lb to three condensing turbines and to process, and a reducing station and desuperheater to furnish 165 lb steam direct from the high-pressure boilers when process demand exceeds the exhaust from the topping turbine. The latter is controlled by the exhaust pressure.

This installation has now been in operation continuously on 24-hr service, except for inspection and cleaning at six-month intervals, for more than three years. At inspections the boilers have been found absolutely clean and free from scale, with complete absence of any sign of corrosion. Such difficulties as were encountered during the initial period of operation had no relation to the high pressure or the steam temperature.

The topping turbine was opened after three years' operation and was found to be in excellent condition, there being a complete absence of blade deposits, thus indicating clean steam and correct feedwater treatment. Availability of the turbine has been close to 97 per cent for the three years and that of the steam-generating units has averaged over 94 per cent, including all outage.

A third and somewhat larger boiler of the same type as the others is now being installed to meet additional steam demands.

Henry Kreisinger, of Combustion Engineering Company, observed that in industrial plants the steam temperature as usually determined is just high enough to give dry steam from the turbine for process work, whereas in central stations the steam conditions are selected for the maximum allowable moisture in the lowest pressure stage of the turbine with the highest safe initial steam temperature, which at present is from 900 to 950 F. Referring to Mr. Ryan's statement that in one-half the high-pressure industrial plants surveyed the initial steam temperature is under 750 F and in more than 90 per cent it is under 800 F, and to the author's suggestion of reducing capital cost by employing lower pressures and higher initial temperatures, Mr. Kreisinger pointed out that the higher steam temperatures would require more expensive superheaters and a desuperheater to bring the temperature of the exhaust to near the saturation point. There is also the greater cost of the high-temperature piping to be considered.

As to operating drawbacks, higher steam temperature would require higher gas temperatures entering the superheater. Since the specific heat of steam is nearly twice that of the gas, 100 deg added to the superheat would mean about 200 deg higher gas temperature. This means that the superheater would have to be placed nearer the furnace, or the furnace would have to be operated at higher rates of heat release, with consequent greater tendency for the superheater to become covered with ash or slag. This would necessitate the installation of soot blowers and provision for hand lancing with the accompanying expenditure of steam for blowing and perhaps additional operating labor for manual cleaning. Also, with a shipment of poor coal, there would be the possibility of reduced steam-generating capacity due to slagging.

Mr. Kreisinger emphasized that no generalizations can be made as to the best or ideal pressure for an industrial plant, as its design is likely to present a more complicated problem in proportion to its size than that of a central station.

L. W. Bates, Bureau of Yards and Docks, U. S. Navy Department, believed that a navy-yard power plant may be classed as an industrial plant inasmuch as its function is to supply light and power, steam for industrial use, building heating, compressed air, water service, etc. During the period covered by Mr. Ryan's paper, the Bureau of Yards and Docks has installed five boilers for 450 lb pressure and one for 650 lb, and within the past year additional boilers for the latter pressure have been ordered. Studies have been made for steam conditions as high as 825 lb and 900 F total steam temperature, but because of the high proportionate steam load very little economy was shown over 600 lb. Consequently, new equipment has been placed in two classifications as determined by piping standard series 40 and 60. To select any higher pressure would throw the piping into the 900-lb classification with a considerable increase in piping cost.

For navy-yard service there can be no standard bleed pressure, because of differences in existing steam-distribution systems requiring various pressures. Studies of non-condensing topping turbines for plants requiring two major steam pressures have indicated that, while the economy of such units is somewhat better than that of the bleeder turbine, they do not, in general, offer as complete flexibility for navy-yard load as do the bleeder machines. Although the topping principle has been adopted in some cases, the topping steam is taken from the high-pressure bleed point of the high-pressure unit.

E. S. Wells, of the General Electric Company, expressed the opinion that the selection of steam pressure and temperature, which may at the time seem adequate to provide a comfortable margin of power generation over the probable demand, has often been found, within a few years, inadequate to meet increased power demands under new conditions. For this reason, he believed it wise to select steam conditions such as to give as much margin as possible without incurring excessive costs.

G. D. Dodd, of Foster Wheeler Corporation, commented upon the importance of proper feedwater preparation for high-pressure industrial power plants and noted that the energy loss resulting from the use of evaporative condensers is less than is commonly supposed. He cited a typical example to illustrate this point.

Kerr Atkinson, of Jackson & Moreland, consulting engineers, while conceding that throttle temperatures are often thoughtlessly selected at too low a value on the assumption that process steam temperature governs the selection, observed that it is frequently possible to compromise the throttle and back-pressure temperatures with some attendant overall gain. For example, where the process involves a large number of steam-driven mechanical drives or where the steam distribu-

tion system is extensive, an increase in the general steam temperature above the existing level may yield increased economy.

Checking over some twenty by-product power studies made by his company, about half of which were actually installed, Mr. Atkinson found four cases in which the steam temperature was set at 675 F. In two of these, installed in 1929, the ratio of steam to power requirements was so great that in the succeeding ten years the by-product power limit has not been exceeded. The other two were fixed by the maximum steam temperature obtainable by remodelling the existing boilers. There was one project fixed at 700 F, with equipment bought for future operation at 750 F. Also there were two recently investigated projects, one for 800 F and the other for 925 F in conjunction with 1250 lb steam pressure. The latter was for operation by a utility. Temperatures of 725 to 750 F were specified for all the remaining cases, this being considered the conservative upper limit for industrial power plant conditions during the period covered by these studies.

M. K. Bryan, of Charles T. Main, Inc., emphasized the author's caution to treat steam utilization and power generation as a joint problem with the object of developing the lowest overall manufacturing costs. In this connection, refinements in process machinery and operations can advisedly be considered in forecasting their effect on the required process steam pressure and the power demands. In some industries there is a noticeable trend toward increased pressure requirements for process use, a decrease in process steam and increase in power consumption per unit of production. Therefore, it would seem prudent, when selecting pressure and temperature, to consider making allowance for a future probable ratio of steam and power.

As to availability, Mr. Bryan cited a number of plants employing pressures of the order of 600 lb and 750 F, with pulverized-coal-fired boilers ranging in capacity from 100,000 to 120,000 lb per hr. These showed 95 to 98 per cent availability for the prime movers and 85 to 90 per cent for the boilers.

A.S.M.E. Three Summer Meetings

For the first time in the history of The American Society of Mechanical Engineers, the 1940 Semi-Annual Meetings will be held in three cities at approximately the same time, although the programs will be different. With simultaneous meetings taking place in Milwaukee, Wis., at the Hotel Pfister, June 17–20; in Ann Arbor, Mich., at the University of Michigan, June 20–21; and in Asbury Park, N. J., at the Berkeley-Carteret Hotel, June 19–22, more members will be afforded an opportunity to attend one group of technical sessions.

Featured at the main meeting in Milwaukee will be thirteen technical sessions with thirty papers covering hydraulics, steam power, education and training, management, fuels, machine-shop practice, process industries, and railroads, several plant trips, luncheons, business meeting and a banquet. The meeting at Ann Arbor, under the sponsorship of the Society's Applied Mechanics Division, will present four technical sessions, devoted to elasticity, dynamics, fluid mechanics and thermodynamics. Besides an exhibit of diesel engines and accessories, the A.S.M.E. Oil and Gas Power Division's meeting in Asbury Park will include twelve technical papers.

MONDAY, June 17, 9:30 a.m.

Turbulence and Energy Dissipation, by A. A. Kalinske
A Theory of Cavitation Flow in Centrifugal Pump Impellers, by Calvin A. Gongwer
Steam-Turbine Blading, by R. C. Allen
Progress in Design and Performance of Modern Large Steam Turbines, by G. B. Warren

7:30 p.m.

Turbine-Blade Fatigue Testing, by R. P. Kroon
Efficiencies Realizable from Large Modern Steam Turbines, by G. B. Warren and P. H. Knowlton

TUESDAY, June 18, 9:30 a.m.

Centrifugal Pump Efficiency Measurements; an Improved Technique, by R. W. Angus
Economic Draft-Tube Proportions, by A. R. Dawson
A Study of Heat Insulation Problems in Steam Power Plants, by E. T. Cope and W. F. Kinney
Experience with Metals at High Temperatures, by A. E. White
Air Pollution Study in the City of Chicago, by Osborn Monnett
Parallel vs. Individual Operation of Multicyclones, by L. C. Whiten, Jr.
Recent Developments in Burning Mid-Western Coal in Water-Cooled Stokers, by H. C. Carroll

WEDNESDAY, June 19, 9:30 a.m.

The Control of Gases in the Wake of Smokestacks, by R. H. Sherlock and E. A. Stalker
Development of a Major Principle in Pulverized Coal Firing, by F. L. Dornbrook
Milwaukee's Contribution to the Development of Pulverized Coal, by Henry Kreisinger and John Blizard

At the Applied Mechanics Sessions at Ann Arbor the following papers on dynamics will deal with certain problems encountered in the design of steam turbines and diesel engines. These are scheduled for June 20.

Forty-Eight Ordinate Harmonic Analysis and the Harmonic Spectrum of Two-Cycle Diesel Torque, by Nancy Klock
Critical Speeds of the First and Second Order of Shafts Supported on Both Ends, by P. Kohn, M. Kampl and J. Bohm
Impulse Blade Vibration, by R. P. Kroon
On the Computation of Axial Vibration Frequencies in Steam-Turbine Disks Especially in Those with Long Blades, by I. Malkin

The Oil and Gas Power Sessions at Asbury Park will include the following papers on diesel engines, engine fuels and the internal-combustion turbine.

WEDNESDAY, June 19, afternoon

Diesel Fuels for Large Unit Power Generation from the Operator's Viewpoint, by J. Bryan Sims
The Houdry Refining Process and the Economic Future of the Diesel Engine, by J. B. Rather

THURSDAY, June 20

Morning

Fluid Couplings, by L. N. Alison
Electric Ship Couplings, by A. D. Andriola

Afternoon

Nordberg's Contribution to the U. S. Maritime Commission Program, by R. W. Bayerlein
Marine Applications of the Diesel Engine, by L. R. Ford

FRIDAY, June 21

Morning

Stress and Deflection in Reciprocating Parts, by R. L. Boyer and T. O. Kuivinen
Engine Balance and Importance as to Design, by Paul Shirley
Frame Stiffness and Engine Vibration, by J. Russel Pyles

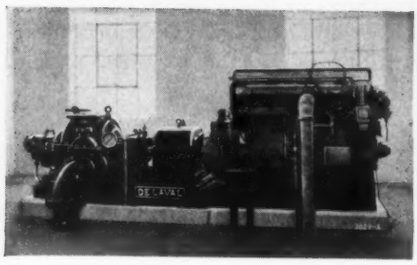
Evening

The Combustion-Gas Turbine, by J. T. Rettaliata

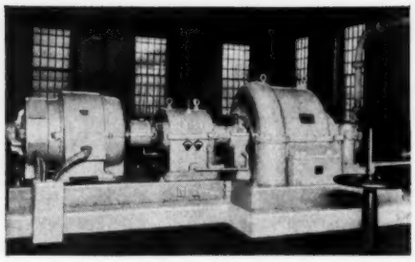
SATURDAY, June 22

Morning

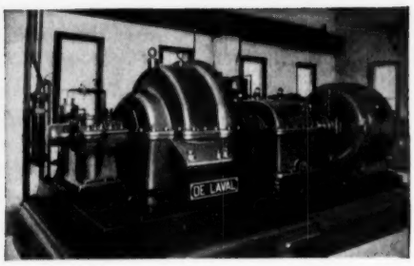
The Significance of Diesel Exhaust Gas Analysis, by John C. Holtz
The Effect of Variations in Atmospheric Conditions on Diesel-Engine Performance, by J. S. Doolittle



Centrifugal compressor in activated sludge service, driven through speed increasing gear by gas engine; 3000 cu. ft. per min. against 8 psi. at 6000 r.p.m. The engine speed is 1200 r.p.m.

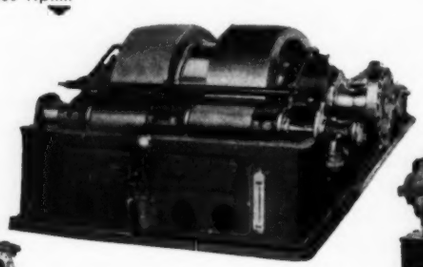


Three-stage gas booster driven at 4000 r.p.m. through speed increasing gear from 1750 r.p.m. motor; 16,650 c.f.m. against 7 psi.

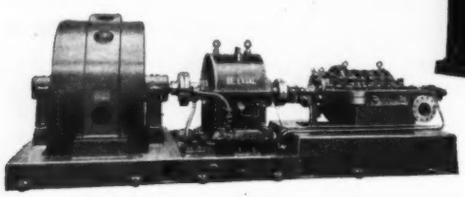


Two-stage compressor in activated sludge sewage disposal plant; 13,500 cu. ft. per min. against 6 psi. at 3600 r.p.m. compressor speed and 1200 r.p.m. motor speed.

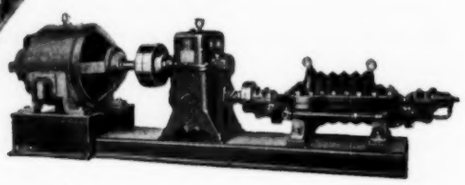
Speed increasing gear to transmit 6000 hp. from a 750 r.p.m. motor to a blast furnace blower operating at 3330 r.p.m.

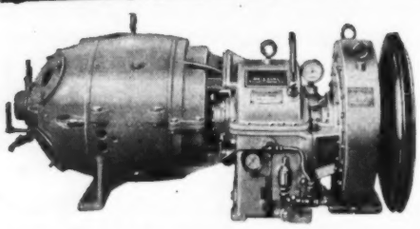


Six-stage descaling pump in a steel mill; driven at 2300 r.p.m. through speed increasing gear from 750 r.p.m. motor to deliver 1000 g.p.m. against 600 psi.



Six-stage boiler feed pump driven at 4000 r.p.m. through helical gear from 1800 r.p.m. motor; 125 g.p.m. of 218° F. water against 525 psi.





Single-stage blower driven at 15,000 r.p.m. through speed increasing gear from a 3000 r.p.m. motor; 1350 c.f.m. against 10 psi. gage.

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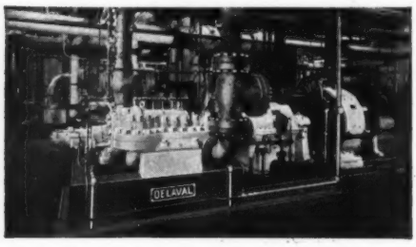

Boiler feed pump driven through helical speed increasing gear by variable speed D.C. motor. At 1200 r.p.m. motor speed and 2475 r.p.m. pump speed, 1185 g.p.m. of 350° F. water is boosted from 500 psi. suction pressure to 1085 psi. for a superposed boiler. The shaft packings are protected from high pressure by labyrinth pressure breakdowns and leak-off chambers at each end of the pump.

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Influence of Copper With Respect to Corrosion in Boilers

By F. R. OWENS, Chemist
Cyrus Wm. Rice & Co., Pittsburgh, Pa.

The source of copper deposits in boilers is generally attributed to surface condensers and closed heaters. The question as to whether such copper losses are caused by the presence of ammonia or other ions is discussed in the light of data collected from a number of plants, as given in the tables. Suggestions are made as to means of preventing, as far as possible, these copper losses in condensers and heaters.

THE presence of metallic copper, and also its oxides and probably complex structures, has been known to exist in deposits in steam boilers for at least two decades.

The primary responsibility of copper, in the feedwater supply and, of course, subsequently in the boiler concentrates, resulting in corrosion in certain instances, is today a moot question. As a matter of fact, the status of our knowledge is such that this question is quite controversial.

The purpose of this discussion, therefore, will not be an attempt to prove or disprove copper as being a primary cause of corrosion in steam-generating units. Rather, it is proposed to present certain facts revealed as a result of our observations within the scope of our experience at certain plants. Obviously, such a revelation must, in some instances, involve a discussion of personal opinion. It is suggested that in such instances the reader retain this thought. Another purpose of this discussion is to stimulate research in this field, and there is also the desire to add to the general knowledge of the art and thereby increase its practical application.

Most of the boilers wherein copper in some form has been found in the deposits have been in central-station power plants, operating with surface condensers. This does not mean, however, that solution of copper and its subsequent entry into the boilers is entirely confined to such plants. We have, however, in this paper confined our data to such plants. Obviously, the source of copper in such plants is two-fold: surface condensers and feedwater heaters. Because of the large surface involved, it is the general belief that the greater loss of copper occurs at the surface condensers. However, in stations operating at high pressures it is apparent that considerable copper losses are experienced at the heaters, as evidenced by the failure of tubes in a number of instances.

The tables which follow show the analytical facts of a small percentage of the relatively large number of plants that have come within the scope of our experience. The tables, we believe, offer a fairly representative cross-section of the field as a whole, although it is not inferred that these data offer complete coverage by any means.

In most cases where copper has been found in the feedwater with resulting depositions in the boilers, the general opinion has been that the loss of copper at the condensers has been due primarily to ammonia in the condensate. The tables accompanying this discussion will show that the concentration of ammonia is quite low. It is, in fact, of such magnitude that, in the light of present-day knowledge, it would be absurd to attempt to reduce it. It appears, therefore, that the solution of copper at the condensers and heaters is certainly not merely a function of the ammonia present. More logical is the conclusion that this loss is due to the solution of the metal as a result of the presence of ions other than NH_4. Wagner[1] showed that the solubility of copper, although being quite low in distilled water at low temperatures, is increased many times by the presence of carbon dioxide. He[2] also showed, that in fairly dilute solutions of the chlorides of sodium, potassium and magnesium, the solubility of copper is increased approximately twenty-eight fold in the presence of carbon dioxide, over its solubility in the same solutions in the absence of carbon dioxide.

TABLE 1—COMPOSITION OF DEPOSITIONS IN CROSS-DRUM BOILER OF 450 LB PRESSURE

	From Steam Drum[1] Per cent	Circulating Tubes Per cent	Water-Wall Header Per cent
SiO_2	0.92	0.51	1.25
Fe_2O_3 (total iron)	18.50	11.10	51.75
CaO	19.00	28.60	Nil
MgO	22.55	26.95	Nil
SO_3	Nil	Nil	Nil
P_2O_5	16.1	19.50	Nil
CuO	Nil	Nil	47.80
Cu	N.D.	N.D.	N.D.

pH of feedwater originally 7.1
pH of feedwater increased to 8.4
Oxygen in feedwater less than 0.05 cc per liter
pH of boiler concentrates 11.0 to 11.2
[1] Deposit magnetic.

Copper is admittedly inactive chemically; however, it is oxidized by oxygen in the presence of moisture. Hence, it seems reasonable to conclude that in instances wherein the ammonium in the condensate is negligible and the presence of the oxides of copper is found in the boilers, that the loss of copper in the condensing equipment is largely due to oxidization and subsequent action of weak acids, such as H_2CO_3. The acetate of copper is

[1] Wagner, *Dingl.*, Vol. 221, 259.
[2] Wagner, *Dingl.*, Vol. 221, 260.

formed with relative ease, in a weak solution of acetic acid in the presence of oxygen.

It has been possible, in some cases, to eliminate copper losses in closed heaters and thereby stop tube failures in such equipment by decreasing the hydrogen ion concentration of the feedwater. McKinney[3] in discussing equilibria in dilute water solutions, states that in a closed system such as this, although the amount and distribution of CO_2 may change with an increase in temperature, the constant G in the electrical neutrality equation will change. In the case of the plant covered under Table 1, tube losses at the heaters were eliminated by increasing the pH of the feedwater. We feel that this is in agreement with McKinney's statement, since the change indicated above at least varied the distribution of the CO_2, even though the quantity did not change. Application of McKinney's method, obviously, may be resorted to in some instances when tube losses in closed heaters are being experienced.

TABLE 2—COMPOSITION OF DEPOSITS IN BOILER AT 950 LB PRESSURE

	Circulating Tubes[1] Per cent	Economizer Drum Per cent	Steam Drum Per cent	Water-Wall Header Per cent	Economizer Header and Tubes Per cent
SiO_2	0.20	0.13	1.33	0.42	0.11
Fe_2O_3 (total iron)	63.00	43.28	72.86	54.74	84.56
CaO	Trace	0.22	0.42	0.20	0.20
MgO	0.65	0.17	1.85	0.51	0.05
SO_3	Trace	0.01	0.06	0.05	0.01
P_2O_5	1.10	5.85	7.08	13.42	6.40
CuO	31.6	49.45	16.40	29.70	8.42
Cu	Nil	0.89	0.00	0.96	0.25

pH of condensate 6.6 to 6.8
CO_2 in condensate 0.40 to 0.60 ppm
NH_3 in condensate 0.15 to 0.30 ppm
pH of feedwater 8.5 to 9.0
pH of boiler concentrates 10.5 to 11.0

[1] Deposit very strongly magnetic.

Attention is again directed to the data in Table 1, and also Table 2. Evidence of pitting in the case of the former was first noted in a water-wall header at a time which was coincident with the discovery of the loss of the protective refractory covering on the header. In the latter case, no evidence of pitting has been noted, but distortion of circulating tubes of sufficient magnitude to necessitate their replacement has been experienced. Readings indicated that the temperatures experienced in these tubes greatly exceed design expectancy. It is worthy of note that the deposit in both instances at the location where difficulties were experienced, consisted largely of oxides of copper. This appears to be significant, and in addition, it should be noted that conditions permitted an excessive heat input at these locations; also, it must be noted that the deposits were magnetic.

In reference to the above, it is of interest to recall that cupric oxide will dissolve in a warm concentrated aqueous solution of either sodium hydroxide or potassium hydroxide.[4] In the two cases discussed, water circulated to the affected areas but free circulation from the area to another section, was not possible. Hence, concentration of all ions and, of course, OH resulted. It is possible, therefore, that with the copper in solution as a result of the action of concentrated hydroxide on copper oxide, displacement by Fe could readily take place, and the activity could be cyclic in the presence of oxygen.

TABLE 3-A—SPECIAL TEST DATA IN CONNECTION WITH OBSERVATIONS OF TABLE 3

Sampled	Tide, Feet	CO_2 Ppm	pH	NH_3 Ppm	Cu Ppm	Specific conductance Mhos $\times 10^{-6}$
Surface condenser condensate	12.8	0.20	7.55	0.01	Nil	1.48
Deaerator	12.5	0.20	8.10	0.015	Nil	1.24
High - pressure heater outlet	12.2	0.20	8.60	0.020	0.005	1.18
High - pressure heater outlet	12.0	0.20	7.40	0.010	0.009	1.55
Surface condenser condensate	16.8	0.20	8.50	0.055	Nil	2.69
Deaerator	17.0	0.20	8.30	0.040	Nil	1.88
High - pressure heater outlet	17.3	0.20	8.00	0.040	0.007	1.57
High - pressure heater outlet	17.5	0.20	8.20	0.040	0.009	1.78
Surface condenser condensate	15.6	0.20	8.30	0.035	Nil	4.76
Deaerator	16.1	0.20	8.50	0.050	Nil	2.44
High - pressure heater outlet	16.5	0.20	N.D.	0.055	0.006	2.28
High - pressure heater outlet	16.8	0.20	N.D.	0.050	0.009	2.45
High - pressure heater outlet	16.0	0.30	N.D.	0.030	0.008	1.67
High - pressure heater outlet	15.4	0.30	N.D.	0.030	0.013	2.38
High - pressure heater outlet	13.6	0.20	6.60	0.013	0.002	1.67
High - pressure heater outlet	13.7	0.20	7.10	0.015	0.006	1.67
High - pressure heater outlet	11.5	0.20	8.50	0.010	0.004	2.53
High - pressure heater outlet	11.3	0.20	7.80	0.010	0.009	2.93

Note: low tide—10 to 13 ft
high tide—16 to 19 ft

CO_2 in condensate, maximum, 0.50 ppm
O_2 in feedwater, 0.00 to 0.009 cc per liter

Another environment must, however, receive due consideration. Hecht[5] showed the existence of hydrogen in steam-generating equipment, due to dissociation of water in contact with iron at high temperatures, and Holmes[6] showed that hot cupric oxide can be reduced by hydrogen. This, of course, would account for the presence of metallic copper. Also, there is the possibility

[3] McKinney, "The Calculation of Equilibria in Dilute Water Solutions." Reprint No. 100, 1939 Annual Meeting A.S.T.M., June 26–30.

[4] Low, *Z. Anal.*, Vol. 9, 463.
[5] Hecht, "Private Data from Special Boiler Tests," 1923.
[6] Holmes, "General Chemistry," The Macmillan Co., 1922.

TABLE 3—DEPOSITS IN BOILERS AT 1400 LB PRESSURE, PER CENT

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	0.19	0.16	0.13	0.25	0.04	0.06	0.26	0.26	0.15	0.29	0.74	12.12
Fe_2O_3 (total iron)	36.00	38.40	5.60	48.80	89.20	28.00	51.20	50.40	3.60	42.00	52.80	29.20
CaO	0.40	0.78	0.62	1.54	0.94	1.98	6.04	4.74	0.66	0.76	1.42	1.28
MgO	1.48	1.17	1.58	1.20	0.06	1.07	1.18	1.33	0.62	1.44	1.05	11.90
SO_3	0.70	0.07	0.63	0.51	0.53	0.60	0.59	0.53	1.10	0.57	0.67	1.63
P_2O_5	4.48	4.37	6.41	3.75	3.88	4.12	4.25	3.78	3.82	4.25	4.74	14.64
CuO	11.30	11.62	19.78	7.62	3.66	10.81	4.60	5.08	12.58	14.30	4.09	Nil
Cu	38.10	39.20	63.80	34.80	N.D.	52.90	31.30	32.30	70.40	32.40	33.40	Nil

(1) Boiler A—60 in. drum, west side
(2) Boiler A—60 in. drum, east side
(3) Boiler A—feedwater header
(4) Boiler A—36 in. drum
(5) Boiler A—steam tubes
(6) Boiler A—floor-tube header
(7) Boiler B—60 in. drum, west side
(8) Boiler B—60 in. drum, east side
(9) Boiler B—feedwater header
(10) Boiler B—36 in. drum
(11) Boiler B—floor-tube header
(12) Boiler B—wall tubes

pH of feedwater 7.5 to 8.4
pH of boiler concentrates 11.0 to 11.2
pH of condensate 7.55 to 8.50
NH_3 in condensate 0.00 to 0.055 ppm

TABLE 4—COMPOSITION OF DEPOSITS IN CROSS-DRUM, SECTIONAL HEADER BOILER AT 700 LB PRESSURE

	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	14.00	15.72	12.90	13.43	12.66	13.58	14.01	14.63	13.07	13.20	13.10	9.88
Fe_2O_3 (total iron)	16.60	18.80	18.20	17.00	17.40	17.40	18.60	16.80	18.00	18.00	16.60	32.00
CaO	15.81	17.26	12.81	12.93	13.80	15.98	18.00	13.83	13.47	22.62	16.27	19.30
MgO	11.53	12.92	11.63	11.15	11.21	11.62	11.94	13.43	10.72	11.50	11.08	16.92
SO_3	0.51	0.51	0.49	0.53	0.43	0.39	0.85	0.69	0.31	0.46	0.42	0.56
P_2O_5	14.60	14.88	13.50	12.59	13.06	16.46	17.46	17.50	14.35	22.63	14.97	17.14
CuO	21.30	13.36	24.43	24.73	25.68	20.93	15.90	14.15	27.85	0.80	23.05	1.12
Cu	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

(1) Boiler A—No. 1 header, main tube bank
(2) Boiler A—No. 3 header, main tube bank
(3) Boiler A—No. 19 header, main tube bank
(4) Boiler A—No. 21 header, main tube bank
(5) Boiler A—No. 37 header, main tube bank
(6) Boiler A—No. 39 header, main tube bank
(7) Boiler A—No. 53 header, main tube bank
(8) Boiler A—No. 55 header, main tube bank
(9) Boiler A—composite from all headers
(10) Boiler A—composite short headers
(11) Boiler A—composite long headers
(12) Boiler A—water wall drums

pH of condensate 7.0 to 8.1
pH of feedwater 7.5 to 8.6
pH of boiler concentrates 10.6 to 10.8
CO_2 in condensate 0.5 ppm
O_2 in feedwater 0.018 to 0.027 cc per liter

of the entry of metallic copper due to erosion in both condensers and heaters.

A study of the data presented in Tables 3 and 4 is of special interest in comparison with the data in Tables 1 and 2. If the reader will recall the experiences in the case of Tables 1 and 2 as we discuss the same for Tables 3 and 4, the interest should be intensified. In the instance of Table 3, very slight corrosive activity has been noted in the economizers and 36-in. drum, whereas at the plant represented by Table 4, no activity has been encountered. It will be noted that in the case of the latter the total iron and copper is much less than in Table 3. Also, Tables 1 and 2 show a much greater total iron and copper content in the areas very definitely affected. In the case of Table 4, environment obviously favored the formation of complex structures in the products resulting through evaporation, as evidenced by the presence of increased amounts of calcium, magnesium, silica, etc.

Table 5 reveals the characteristics of the deposit

TABLE 5—COMPOSITION OF DEPOSITS IN GENERATING TUBES OF CROSS-DRUM BOILER AT 585 LB PRESSURE

	Per cent
SiO_2	2.79
Fe_2O_3 (total iron)	50.00
CaO	15.36
MgO	6.46
SO_3	0.58
P_2O_5	16.55
CuO	Nil
Cu	Nil

Iron is all present as Hematite
pH of condensate 6.7 to 6.8
CO_2 in condensate 1.0 to 1.5 ppm
pH of feed water 6.8 to 7.0
O_2 of feed water 0.0 to 0.01 cc per liter
pH of boiler concentrates 11.0 to 11.2 cc per liter

encountered to be materially different from those of the previous cases discussed. The entire absence of copper is quite significant, and also the iron exists entirely as Hematite; whereas, in the case of Tables 1 and 2, the deposits were strongly magnetic and those in Tables 3 and 4 slightly so. The boilers involved in the case of Table 5, after nine years service, show definitely no evidence of corrosion. Attention is also directed to the preponderance of calcium in this instance, which is not true for most of the deposits in the first four examples.

Return now to Table 3-A, which covers data obtained in an attempt to determine if a relationship exists with respect to the copper content of the condensate and feedwater and the ammonia concentration or tide. The data appear to be negative in this respect. However, we must admit the obvious, that the NH_3 concentrations found are quite low.

In Table 6 is shown the type of deposit found in the same boiler with and without the administration of sodium sulphite into the feedwater. In addition to a marked difference in the chemical characteristics of the depositions, the amount of the deposit increased considerably with the use of sodium sulphite.

Figs. 1 and 2 are reproduced from photomicrographs of two sections from the same tube in which a deposition was encountered which consisted largely of copper oxide and magnesium oxide of iron. Both photomicrographs were taken at a magnification of 100 diameters and in each case the etchant was 5 per cent Nital. Fig. 1 represents a section of the tube in the area at which the above-mentioned deposit was encountered. Fig. 2 represents a section where the deposition was not experienced. The microscopic examination reveals no difference in the structure of the metal at the two localities.

TABLE 6—COMPOSITION OF DEPOSITS IN TUBES

	Tube Deposit[1]	Tube Deposit[2]
SiO_2	0.83	0.20
Fe_2O_3 (total iron)	69.20	63.00
CaO	0.20	Trace
MgO	7.14	0.65
SO_3	0.60	Trace
P_2O_5	12.86	1.10
CuO	3.58	31.60
Cu	0.65	Nil

[1] Deposit formed during period that sodium sulphite was used.
[2] Deposit from same tubes as [1] but during a period that sodium sulphite was not used.

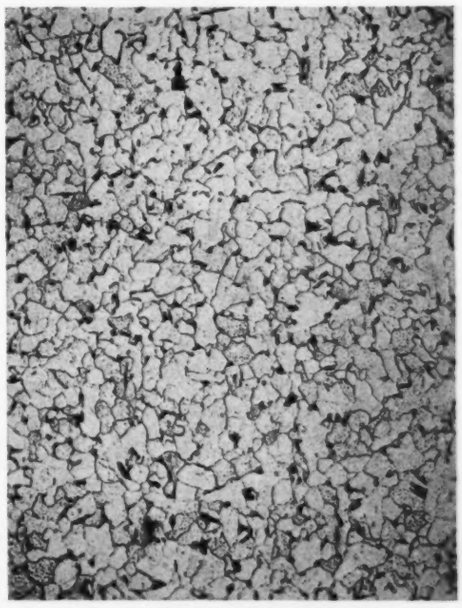


Fig. 1—Photomicrograph of tube section where copper oxide and magnesium oxide of iron deposits were found

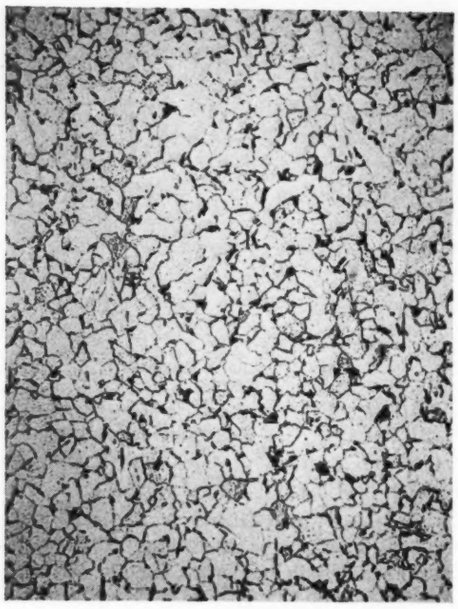


Fig. 2—Photomicrograph of same tube as Fig. 1 but in section where deposit was not encountered

Conclusions

One must recognize the existence of very definite limitations with respect to chemical means of preventing copper losses at surface condensers and to a lesser extent at the closed heaters.

The best means available should be resorted to for deaeration; not only from the viewpoint of oxygen removal is this essential, but for CO_2 and NH_3 as well.

Any changes in chemical treatment which tend to establish electrical neutrality in the system should be resorted to.

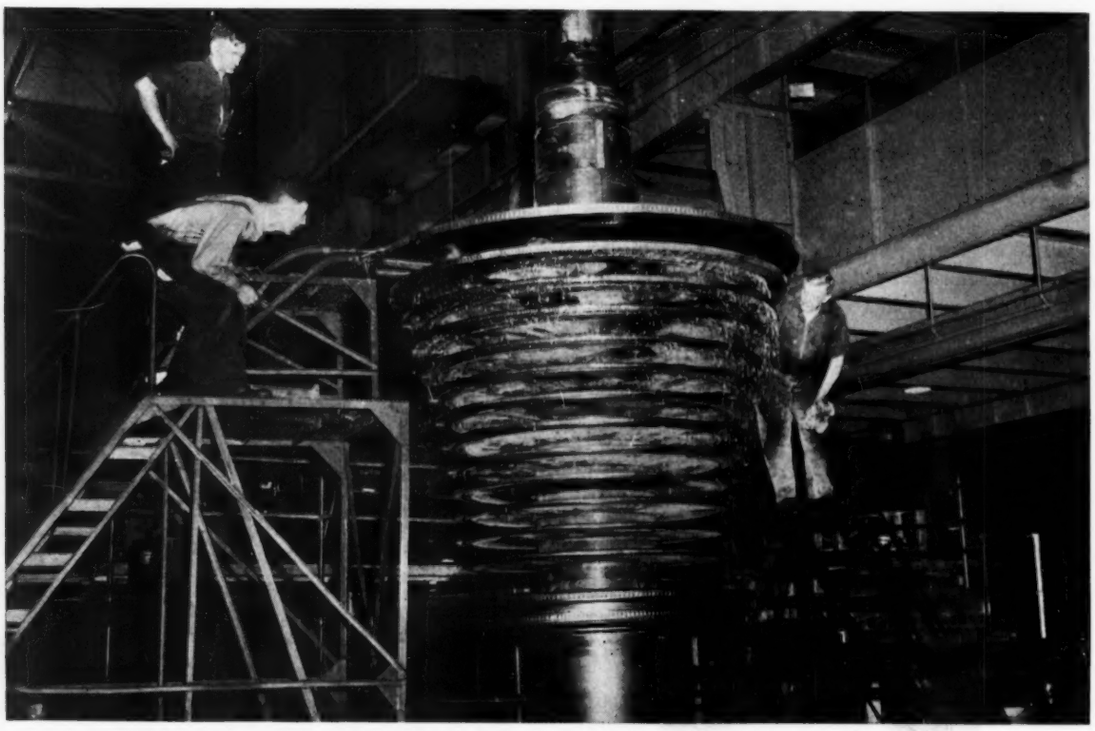
Obviously, mechanical conditions which permit an excessive heat input to local areas within the boiler, with resultant dry areas, should be corrected when possible.

The presence of copper in some form in the deposits in boilers does not necessarily forecast corrosion. Hence, if this material is present it need cause no undue apprehension. Its presence should, however, be sufficient to warrant intensive investigation and continual vigilance for any evidence of undesirable activity. Strict supervision should also be exercised for evidence of changes in mechanical or chemical environment.

The highly controversial status of this and kindred subjects is largely due, as McKinney indicates, to the meager applied research on equilibria as it pertains to dilute water solutions. If this discussion stimulates, even though slightly, present studies in this field, it will have justified its existence.

Shrinking Bucket Wheels on Turbine Shaft

The photograph below was taken in the shops of the General Electric Company at Schenectady during the process of shrinking bucket wheels on the shaft of a 50,000-kw turbine. The procedure involves uniform expansion of the wheels by heating in a furnace to 180 C, after which the wheels are slipped over the shaft in vertical position, one at a time. Contact to a tight fit is effected by shrinkage through spraying with cold water as shown.



Water is sprayed on the heated wheels to effect a shrink fit

Intermittent Burning of Gas and Pulverized Coal*

By H. A. KLEINMAN

Peoples Power Co., Moline, Ill.

A review of the principal differences in operating characteristics that show up in changing from pulverized coal to natural gas, or vice versa. These are especially important with units operating at high total steam temperatures where the maintenance of uniform steam temperature may present a problem. Also, the simultaneous use of these fuels is likely to interfere with the proper functioning of automatic combustion control and it becomes necessary to determine the proper CO_2 to carry for each mixture.

DURING the past eight or nine years natural gas has been supplied to many communities in the Middle West and, as a result of the load factors on the domestic, commercial and industrial business, a certain amount of gas has been available for boiler fuel on an "interruptible" basis. In this case "interruptible" means that the customer agrees to discontinue the use of boiler gas at any time requested and for any duration of time upon very short notice. This may be one hour or twenty-four hours, depending upon conditions.

It follows then, that for continuous operation, the boiler-gas customer must be prepared to burn more than one fuel. For this reason, boilers equipped to burn gas are usually also equipped to burn oil or coal, because it is advantageous to change fuels under the same boiler rather than put on a coal or oil-fired unit to replace one that is gas-fired, and then reverse the procedure when gas is again available. In order to meet these conditions, a number of combination arrangements are in service, such as gas and oil burners, gas burners and stokers and gas and pulverized-coal burners. The writer will discuss only the last combination, namely, gas and pulverized coal for central-station boilers so arranged that the change from one fuel to the other is made in a few minutes without disturbing the output of the unit. Of course, both fuels may be burned simultaneously, which is often the case when the supply of gas is limited to a definite daily amount not sufficient to provide the required steam output.

To simplify the discussion, the use of one pound of coal having a heat value of 10,000 Btu will be compared with the use of one-half pound of natural gas, which is about 10 cu. ft. and has a heat value of approximately 10,000 Btu, burned in a steam generating unit making steam at 825 lb. gage and 825 F total temperature from feedwater at 212 F. The unit has a completely water-cooled, continuous slag-drip furnace, convection superheater, economizer and air heater, also both forced- and induced-draft fans.

Combustion of Coal and Gas

One pound of coal can be burned completely with 20 per cent excess air, giving a CO_2 of 15.3 per cent. It will require 9 lb of air from the forced-draft fan, and form 10 lb of flue gases which will occupy 125 cu ft at 60 F, 30 in. of mercury and have a density of 1.025, when air equals one. A certain amount of air infiltration and leakage through the unit increases the gas volume to 136 cu ft at 60 F, 30 in. of mercury. This weighs 10.6 lb, which is the gas handled by the induced-draft fan, and of which one-half pound is water vapor.

The actual volumes of the flue gas vary with the temperature and if the entire 10,000 Btu liberated from one pound of coal appears as sensible heat in the flue gases, their temperature will be around 3500 F. The flue gases from one pound of coal will occupy 950 cu ft in the furnace. As the sensible heat is absorbed from the flue gases the volume decreases until, at the release temperature of 320 F, the flue gases from one pound of coal occupy 203 cu ft, which is the actual volume handled at the induced-draft fan.

Ten cubic feet, or one-half pound, of natural gas can be completely burned with 10 per cent excess air, giving 10.8 per cent CO_2 and requiring 8 lb of air from the forced-draft fan. There is formed $8\frac{1}{2}$ lb of flue gases which will occupy 115 cu ft at 60 F, 30 in. mercury, and have a density of 0.965, when air equals one. Air infiltration will increase the volume to 124 cu ft and the weight to 9.2 lb by the time it passes through the induced-draft fan; of this, one pound will be water vapor.

The actual volume of the flue gases from 10 cu ft of gas will be 920 cu ft in the furnace for a temperature of 3740 F, based on the assumption that all the heat of combustion appears as sensible heat in the flue gases. This volume is decreased as the heat is absorbed by the heating surfaces until at the release temperature of 295 F the flue gases from 10 cu ft, or one-half pound, of natural gas occupy 180 cu ft which is the actual volume handled at the induced-draft fan per 10 cu ft of gas burned.

This comparison shows that the volume of air and flue gas and the resulting velocities are less when burning gas than when burning coal, which means that less fan power is required to burn gas than to burn coal; or, conversely, the same fan power will develop a higher output when gas is the fuel than will be developed when coal is burned. The comparison also shows twice as much water vapor in the flue gas as is present in the flue gases from coal. The practical significance of this is in its

* From a paper before the Midwest Power Conference, Chicago, April 9 and 10, 1940.

effect on the efficiency of the unit and on the dew-point of the flue gases. The effect on the efficiency of the unit will be referred to later, and as to dew-points it may be noted that condensation in the economizer and air heater will occur at a higher temperature when burning gas than it will when burning coal. This effect should be given careful consideration in regard to correction resulting from condensation of flue gases especially at the lighter loads.

Automatic or Manual Control

Attention is called to the difference in CO_2 content of the flue gases resulting from the burning of the two fuels. That resulting from complete combustion of the coal under discussion with no excess air would be 18.6 per cent; and 20 per cent excess air gives a CO_2 reading of 15.3 per cent. When burning the gas completely with no excess air the CO_2 is 12 per cent; or with 10 per cent excess air 10.8 per cent CO_2. Varying mixtures of coal and gas give CO_2 readings varying over a wide range so that, if using CO_2 readings, one must take account of these conditions and also determine whether or not the instrument being used will give correct indications on either fuel, or varying mixtures of them.

For the unit under consideration, a chart has been prepared from which it is possible to determine the proper CO_2 for varying mixtures of gas and coal, based on the readings obtained from a gas meter of the orifice type and from a steam-flow meter. The fireman observes the static pressure and differential pressure on the gas meter and the pounds of steam per hour on the steam-flow meter. From these three, instrument readings and the chart, the fireman can determine the proportions of gas and coal being burned and the proper CO_2 to carry for the proportions so determined. He then adjusts the air supply to obtain this CO_2 reading.

The variation in steam flow–air flow relationship because of changes in required excess air causes difficulty when attempting to operate on automatic control. When burning both fuels simultaneously on varying loads, it is almost necessary to operate manually in order to keep a close check on the actual CO_2 content of the flue gases and to maintain this content at the proper value for the mixture being burned.

Furnace Design

The fuels must be properly introduced, intimately mixed with air and everything possible done to promote the chemical reaction producing carbon dioxide and water vapor, with a minimum of excess oxygen and unburned fuel accompanied, of course, by the inert nitrogen. The furnace must provide the volume necessary to contain the gases, expanded to six or seven times their initial volumes, and be long enough to complete the reactions. The gas burners, therefore, should be close to, or within, the coal burners so that the supply of air from the forced-draft fan is immediately available to both the fuels as they are introduced into the furnace. It so happens that both fuels require about the same length of travel and the same furnace volume and can, therefore, be burned in a common furnace. The furnace must withstand the temperatures developed, provide for the removal of ash, and absorb sufficient heat to reduce the temperature of the leaving gases to a temperature lower than the softening point of the ash from the coal, so as to reduce slagging troubles in the first rows of boiler tubes and in the superheater.

Final Steam Temperatures

With the higher steam pressures and temperatures, the work done in the superheater has increased until at present 16 to 20 per cent of the total heat absorbed by the water and steam is taken up in the superheater, as compared to 5 to 7 per cent when generating steam at 200 lb pressure and 550 F total temperature. The superheater, therefore, has become proportionately two to three times larger and the problem of superheat control has become correspondingly more difficult. It is difficult enough when only one fuel is used but becomes much more difficult when it is necessary to maintain a nearly constant final steam temperature when shifting from solid fuel to gaseous fuel, and vice versa.

Superheater bypass dampers do not give sufficient control to cover this change, although they will do well on one fuel only. In the unit under discussion, the final temperature of the steam during a test at rated output on gas with the superheater bypass damper closed, which gives the highest steam temperature attainable under the conditions, was 795 F, which is 30 deg lower than the temperature desired. In another test at the same rating on coal this temperature was 846 F with the superheater bypass damper open, which gives the lowest temperature attainable under the conditions but still 21 deg higher than the desired temperature. The importance of constant and proper temperature in this range becomes more apparent when it is realized that the creep of the metals used in turbine construction is apt to double for each 20 deg F above the design temperature.

There are several reasons for a change in final steam temperature when changing fuels from coal to gas, and vice versa. As already pointed out, the volume of flue gas when burning gas is less than that from coal. This means a lower velocity through the superheater which tends to reduce the rate of heat transfer. The flames from gas and from coal have quite different luminous properties and change the rates of heat transfer by radiation from the flames to exposed heating surfaces. The change hardest to cope with, however, is that due to the ash in the coal. When the furnace walls are clean, the final steam temperature may be 75 deg less than the final steam temperature after the furnace walls become covered with slag. When burning gas, the slag coating comes off, leaving the bare walls and causing a change greater than can be compensated for by use of the superheater bypass damper.

In attempting to control the final steam temperature, certain portions of the furnace walls were covered with refractory material in order to raise the superheat when burning gas. This provided a permanent hot furnace wall surface in place of the variable slag surface that comes off when burning gas. Also, a second bypass damper was constructed, allowing flue gases from the furnace to pass directly to the economizer. This damper is quite effective but operates at temperatures in excess of 2000 F, which makes it an interesting structure. The economizer and air heater picked up the heat bypassed around the boiler and superheater. The rise in final release temperature was very slight, so there was no appreciable sacrifice in unit efficiency. This situation has been discussed at some length because it is a common

problem with units burning both coal and gas to generate steam at high temperature. Supherheat control based on bypassing a portion of the steam through tubes located in a boiler drum promises to give sufficient range of control to make possible the attainment of constant final steam temperatures over a wide range of loads and with more than one fuel.

It is interesting to note in passing that the quantity of air used for combustion has a marked effect on the steam temperature. For example, when burning coal with 20 per cent excess air, the steam temperature was 773 F. As the excess air was increased to 45 per cent with a CO_2 of 12.5 per cent, the steam temperature increased to 857 F, a rise of 84 deg, but with a loss in overall unit efficiency of 2.2 per cent. When burning gas with 10 per cent excess air, the steam temperature was 763 F. As the excess air was increased to 40 per cent, with a CO_2 of 8.4 per cent the steam temperature increased to 839 F. A rise of 76 deg but with a loss in overall efficiency of the unit of 1.5 per cent.

Efficiencies

The effect on efficiencies of the various factors mentioned can be indicated by following the pound of coal and one-half pound of gas through the unit and pointing out the distribution of the ten thousand btu that each contains when the steam generating unit is operated at normal full load output. When fired with coal, the $10^1/_2$ lb of flue gas containing $^1/_2$ lb of water vapor is discharged at 320 F carrying with it 1125 Btu of which about 500 Btu is latent heat of vaporization of the water vapor. When fired with gas, the 9.2 lb of flue gas containing 1 lb of water vapor is discharged at 295 F, carrying with it 1450 Btu of which 1000 Btu is latent heat of vaporization of the water vapor. The principal difference to note in this comparison is the loss due to the combustion of hydrogen in the natural gas which results in a water vapor loss of twice as much as with coal even though the coal considered here contained over sixteen per cent moisture as fired.

Losses other than that in the flue gas when burning coal are those due to unburned carbon, radiation, heat in the slag, unburned fuel in mill tailings and heat absorbed in the water-sealed ashpit, totaling 175 Btu per 10,000 Btu in the fuel supplied. The total losses with coal are 1300 Btu, which means that 8700 Btu are absorbed in the water, steam or air, giving a unit efficiency on coal of 87 per cent.

Losses other than flue gas losses when burning gas are those due to unburned fuel, radiation and heat absorbed in the water-sealed ashpit, totaling 150 Btu per 10,000 Btu in the fuel supplied. The total losses with gas are 1600 Btu which leaves 8400 Btu to be absorbed in the water, steam or air, giving a unit efficiency on gas of 84 per cent.

It is interesting to analyze the heat absorbed and see how much is picked up in the air heater, economizer and superheater. In this case it is found that when burning coal, 8700 Btu is absorbed per 10,000 Btu input, of which 750 Btu is taken up in the economizer, 6000 Btu in the boiler and furnace walls, 1450 Btu in the superheater and 500 Btu in the air heater. On gas, 8400 Btu is absorbed per 10,000 Btu input, of which 700 Btu is taken up in the economizer, 6000 Btu in the boiler and furnace walls 1325 Btu in the superheater and 375 Btu in the air heater.

Summary

The foregoing refers briefly to the principal differences in operating characteristics that are apt to show up in changing boiler fuel from coal to gas, and vice versa. In the case of boilers operating with 100 deg superheat or less, none of these problems are likely to be important, but with units operating at 300 deg of superheat or more, control of the final steam temperature may present some rather difficult problems. If the superheat is correct when burning coal, it will be low when burning gas. If this condition is satisfactory, then there is no problem, but if it is necessary to maintain a constant final steam temperature over a wide range of loads and with two different fuels, then the problem becomes more difficult and requires careful consideration. The simultaneous use of both fuels is likely to interfere with the proper functioning of automatic control based on steam flow–air flow relationships and this makes it necessary to know the actual CO_2 and determine the proper CO_2 to carry for each mixture.

To compensate for these difficulties, however, the natural gas burners provide a very satisfactory means of lighting off the pulverized coal burners and offer an excellent immediate standby to maintain the output of the unit in case of an interruption in mill operation. Furthermore, gas is an ideal fuel. It is easy to burn, easy to measure and very clean, not only in the furnace and flue gas passages, but throughout the plant, with the result that its use is attractive even when obtained on an intermittent basis.

An Enviable Smoke Abatement Record

"The Industries of Hudson County, New Jersey have made an excellent showing in Smoke Abatement," according to William G. Christy, Smoke Abatement Engineer of Hudson County, in releasing the second part of his annual Report. During the year 1939, County Smoke Inspectors made 26,325 observations of stationary plants chimneys and saw only 118 violations of the Smoke Ordinance. The violations constituted only 0.45% of the observations. During the year 1931, the first year the Department of Smoke Regulation was in operation, there were 547 stationary plant violations out of 5987 observations. This figures out as a 92 per cent improvement during the year 1939, as compared with 1931. The classification of stationary plants includes heating plants also, but most of the observations and violations were on industrial plants.

Total stack observations on railroads, industries, heating plants, floating equipment, dumps and portable equipment, amounted to 44,799. Violations observed totaled 291, or 0.65 per cent. There was less than 1 violation per day throughout the year. During the year 1931, there were 1702 violations out of 13,436 observations. This figures out as an improvement of more than 94 per cent.

All the records made by the Department of Smoke Regulation indicate that over 90 per cent of the Smoke formerly made in Hudson County has been eliminated. This condition has all been brought about by cooperation on the part of owners and operators.

Don't Forget—

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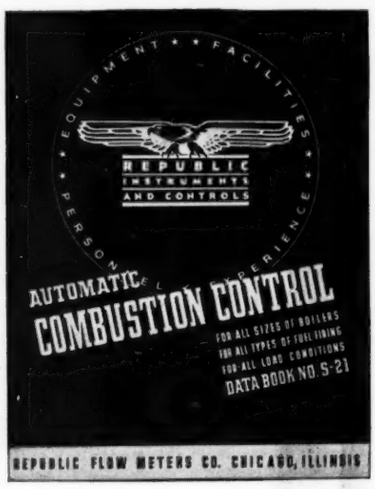
To realize all the financial and operating advantages of modern boilers, they must be closely controlled. In order to maintain highest boiler efficiency a number of repetitive adjustments must be made frequently and practically simultaneously on several units of auxiliary equipment. The difficulty of making the required repetitive adjustments accurately and synchronously by hand at the individual auxiliaries is obvious.

The REPUBLIC-SMOOT combustion control system will operate your boiler at test efficiency for long periods. It enables you to obtain every economy of which your boiler is capable by assuring correct operation—the second vital factor in low steam cost.

It does this by placing each unit of fuel and air supply equipment under the control of an individual Republic-Smoot regulator and co-ordinating the entire system by means of a master controller. This device causes the regulators to adjust fuel and air supply to the boiler in the correct amount to maintain constant steam pressure and in the correct ratio to maintain maximum combustion efficiency. The master controller is fully compensated, the regulators measure the quantities they control and are individually stabilized to prevent hunting. The entire control system is a simple, rugged machine—sensitive, fast and powerful.



REPUBLIC-SMOOT combustion control systems are designed and built for all sizes of boilers—all types of fuel firing equipment—all load conditions. They fulfill all the conditions of theoretically perfect combustion control and still meet all the demands of every-day operating requirements.

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Third Midwest Power Conference Held at Chicago

APPROXIMATELY five hundred engineers from various sections met at the Palmer House in Chicago on April 9 and 10 for the Third Midwest Power Conference, sponsored by Armour Institute of Technology with the cooperation of seven midwestern colleges and local engineering groups. A diversified program included sessions on fuel burning problems, small power plants, hydro power, electrical transmission and the production of power and process steam in industrial plants. There were also several luncheon meetings at which addresses were given and a banquet at which James W. Parker, Vice-President of the A.S.M.E., spoke on "Evolution of the Engineer" and F. Malcolm Farmer, President of the A.I.E.E., discussed "The Engineer and His Profession." The following deals with only a few of the papers presented:[1]

Maintaining the Optimum in Steam Generator Efficiency

Parker A. Moe told of the methods employed in the power plant at the Milwaukee Works of the International Harvestor Co. to maintain optimum efficiency. This plant, erected in 1928 and 1929, includes five pulverized-coal fired steam generating units having an aggregate capacity of 300,000 lb of steam per hour. These units have air-cooled refractory furnaces, rear water walls, superheaters, economizers, soot blowers, fly ash collectors and a complete set of indicating and recording instruments. For the past ten years of continuous operation the thermal efficiency of the steam generating units, as reported by Mr. Moe, has averaged 89.9 per cent, with an average stack temperature of 281 F. Furthermore, during this period there have been no forced shutdowns, and no replacement of suspended furnace arches or refractories, except a few door arches and minor repairs, despite an average CO_2 of over 15 per cent. Barring the loss of a few superheater tubes, there have been no tube losses in the boilers, water walls or economizers. In listing the practices employed to obtain this remarkable record, Mr. Moe stressed the training of personnel, safety measures, proper regulation of draft and maintenance of the desired CO_2 without smoke. In this connection it was important to determine the possibilities of the steam generating units with respect to the effects of high CO_2 on furnace temperature, stack temperature and efficiency, and to definitely establish the limits of CO_2 over the entire operating range.

Operating charts, showing the stack temperatures corresponding to the CO_2 and boiler ratings, are used as a guide for the operators. Since maintaining pulverized-coal furnace refractories in good condition requires proper control of furnace temperatures and flame placement, each operator has been trained very thoroughly in this respect. The coal has been selected carefully, evaporation tests being run for at least a two-week period, and the various coals tested being burned under the same boiler at like ratings, while the remaining boilers were operated with the test coal at fluctuating loads. Lake Michigan water, softened by a lime-soda, hot-process softener, analyzed three times daily, has been used and has resulted in only a very slight scale formation and excellent tube maintenance.

All fly ash and carbon which accumulates in the fly ash traps is recirculated through the mills and returned to the furnaces. Complete boiler inspections are made every six months and all repairs recorded. Continuous records are kept of the time each unit is run and the time over a period of years is equally distributed between the units. A complete set of records and thirty curves, plotted daily, are kept of all equipment and of the personnel operating the equipment. When a drop in efficiency is noted it is immediately investigated and corrected.

Steam Generator Design

Listing low ash-softening and fusion temperatures, small coking tendency, high moisture content and low to moderate grindability as characteristics of midwestern coals that influence the design of steam generators for burning such fuels in pulverized form, Martin Frisch proceeded to explain how the problems arising from these characteristics may be met.

Most midwestern coals are easy to burn in pulverized form, even when coarsely pulverized, because their tendency to coke is small and they are naturally free burning. However, the ash usually slags readily, which fact renders them more troublesome than most native coals. Such slagging may be responsible for reduction of capacity if continuous cleaning is not employed to keep the slagging in check, although by suitable design hand lancing may be kept to a minimum. Fine grinding will also reduce slagging difficulties. Slag control becomes more difficult as the capacity of units increase.

Increases in steam generator capacity generally involve proportional increases in furnace volume. Actually, as unit sizes increase, other conditions being the same, furnace volumes should be increased more rapidly than proportionately if the same exit temperature and the same freedom from slagging of heat-absorbing surfaces are desired. As the furnace size is increased the area of walls, roof and floor per cubic foot of volume, available for radiant heat absorption, decreases. If the furnace heat release be maintained constant, the exit gas temperature inevitably rises as the furnace size is increased.

Mr. Frisch explained that there are two "outs" for this dilemma. One is to reduce the furnace heat release rate as the capacity is increased, and the other is to increase the amount of heat absorbing surface per cubic foot of volume. The first is easy to accomplish if space is available, whereas the second may be resorted to if

[1] The complete program appeared in the February 1940 issue of COMBUSTION and the *Proceedings* will be available shortly.

the space is limited. The second method involves the subdivision of furnace volume into two or more furnaces by using radiant heat absorbing partition walls. Each subdivision adds two walls with a possible increase of 25 to 30 per cent in the cooled wall surface per cubic foot of furnace volume with a corresponding reduction of about 100 deg in the furnace exit temperature. However, while low furnace exit temperatures are desirable with midwestern coals if slagging of surfaces is to be minimized, the final steam temperature will limit the exit gas temperature.

Mr. Frisch then, by curves, showed the effect of furnace exit gas temperature on superheater design for different final steam temperatures and loadings, discussed the use of radiant superheating surface and explained how the multiple furnace is fired to maintain the desired superheat control.

The Combustion Gas Turbine

Paul R. Sidler discussed the development work of Brown, Boveri & Co. in connection with the Holtzwarth gas-turbine cycle since 1909, particularly with reference to supercharging. Since 1923 approximately a thousand exhaust-gas turbine-driven supercharging blowers have been built, of which over a hundred are in operation in this country in locomotive, marine and stationary applications. Development of the Velox steam generator brought about the need for an efficient air compressor and resulted in the building of an axial-flow compressor which converted the former power deficiency into a surplus.

"This earlier work," said Mr. Sidler, "provided the three fundamental requirements for a successful combustion gas turbine, namely, an accurate knowledge of thermodynamics of gas combustion, materials able to withstand the physical and chemical action of the combustion gas at temperatures from 1000 to 1100 F, and an air compressor with sufficiently high adiabatic efficiency."

Equipped with this knowledge, it became possible successfully to approach larger supercharging problems, as encountered in chemical processes, such as the widely publicized Houdry process of catalytic oil cracking. Requiring large volumes of air to reactivate its catalyst, by burning off coke and carbon deposits at regular intervals, this operation is carried out under a pressure of 50 lb per sq in. and the resulting gas, issuing at a temperature of 900 to 950 F, is expanded in a gas turbine which provides surplus power.

In the gas turbine, as applied to power generation, atmospheric air is compressed to about 60 lb per sq in. and 360 to 380 F. It then enters a combustion chamber where it is subdivided, about 25 per cent passing to the oil or gas burner and 75 per cent being bypassed around the burner to dilute the products of combustion and reduce the temperature of the mixture to around 1000 F. This represents the present continuous temperature limit for the turbine elements, although short-time peaks up to 1120 F are permissible. The pressure drop through the combustion chamber is about $1^1/_2$ lb so that the mixture enters the turbine at $58^1/_2$ to 59 lb gage. It is then expanded through six or seven reaction stages and leaves at a temperature of 600 to 615 F. Although, in the simplest layout, this gas is discharged to atmosphere, it would be possible to utilize this exhaust heat at the expense of a small back pressure for preheating the combustion air leaving the compressor.

Experience has shown that if the product of the adiabatic efficiencies of the gas turbine and of the compressor is 53 per cent, the power surplus is zero. However, in a machine such as used in connection with the Houdry process the adiabatic efficiency of the turbine is 86 per cent and that of the compressor 85 per cent, making their product 73 per cent. The corresponding overall thermal efficiency of the turbine-compressor set is about 17 per cent, as confirmed by tests. If an air preheater be included this efficiency would be increased to 21 per cent.

Although the gas turbine so far is available only for oil or gas fuel, experimental work is being conducted with pulverized coal. While the present thermal efficiency, as limited by permissible temperatures with available turbine materials, is not sufficiently high to be attractive for primary power generation, the gas turbine, with its rapid starting abilities, has possibilities for standby and peak-load service. That it requires no water is a factor in its favor for certain locations where cooling water is not available.

Dual Fuel Burning Diesel Engines

The availability of natural gas on an "interruptible" basis as an engine fuel has been responsible for the design of engines capable of burning either oil or gas, to insure continuous operation. The pioneer work in development of such engines by the Nordberg Manufacturing Company was reviewed by H. W. Dow of that company.

These particular engines are of the two-stroke-cycle type and operate on the true Diesel cycle whether burning oil or gas in contrast with other convertible designs that operate on the Otto cycle when burning gas and are generally of the four-stroke-cycle type. The Diesel cycle is more efficient, especially at fractional loads, because of the higher temperatures and pressures employed.

The dual fuel burning engine incorporates all the features of an air-injection type of engine and is equipped with a three-stage compressor which compresses the gas fuel to 1000 lb gage.

To change such an engine over from gas to oil the compressor is purged of its gas contents and it is then ready to pump air for injecting the oil. Such engines produce a kilowatt-hour on 11,000 Btu at full load and 11,500 Btu at three-quarters load.

Protection of Power Plant Equipment Through Insurance Inspection

At the first luncheon meeting a paper by Dale F. Reese, Vice-President of the Hartford Steam Boiler Inspection and Insurance Company, was presented, in his absence, by W. D. Halsey of that company. The author divided power plant insurance into two main groups, namely, boiler insurance which covers boilers and pressure vessels, and machinery insurance, which covers all classes of wheels, engines, turbines, pumps, compressors and electrical equipment. The direct property insurance policy, applying to either boilers or machinery, primarily undertakes to reimburse the

policy holder for loss sustained on property of his own which is damaged by an accident and to cover for him also such liability as may accrue from loss on property of others damaged by the accident. This may include a provision for funds available for providing overtime work by repair men, temporary repairs, etc.

Another type of loss, an "indirect loss," is covered by three different forms of protection, namely, Use and Occupancy, Outage and Consequential Damage. The first applies to loss from reduction or stoppage of income from business normally conducted on the specified premise; the second applies to loss arising from increases in cost of operations necessary for carrying on business, because of outage; and the third deals with indirect damage to property resulting from lack of heat, light, power, steam or refrigeration.

"Boiler and machinery insurance," said Mr. Reese, "differs greatly from all other forms of insurance, principally in that its basic aim is, by means of well-regulated inspection service, to reduce the number of accidents." Hence, power plant insurance activities are by nature perhaps 80 per cent engineering and only 20 per cent underwriting.

Trends in Power Demand Show Increased Commercial and Domestic Load

Addressing the second luncheon meeting, L. W. W. Morrow cited figures indicating the growth in residential and commercial load as the most stable class of utility load. While the total output of electricity in 1939 was 36 per cent over that of 1929, only 50 per cent was supplied to industry, whereas twenty years ago such load accounted for 65 per cent. In discussing the technological and economic aspects of the country's power supply, he stressed the superiority of relatively small plants at load centers with energy distributed locally as compared with large plants and grid transmission, and the necessity of backing hydro installations with steam power plants.

Among the other papers was one on "Power Fallacies" by P. W. Swain who mentioned that, contrary to the general impression, steam requirements in industry far outweigh power requirements. He also referred to the widespread misconception in the public mind that the chief item of cost of delivered electricity is that of the fuel burned—a belief that is largely responsible for the present unwarranted importance attached to the development of hydro power. As a corrective measure, he advocated that the public be given the benefit of evaluations by engineers who have no commercial stake, either in the utilities, on the one hand, or in government ownership, on the other.

Philip Sporn, speaking on the protection of high-voltage lines, said that present developments with carrier relaying and high-speed breakers permit a line to be opened, cleared and closed in from 18 to 20 cycles, at which speed there is little or no disturbance noticeable on the system.

A paper by H. A. Kleinman on the "Intermittent Burning of Gas and Pulverized Coal" is abstracted rather fully elsewhere in this issue. It explains the difference in operating characteristics when changing from one of these fuels to the other.

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REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Boiler Feedwater Treatment

By F. J. Matthews

This is the second edition, the text of the 1936 edition having been partially revised, extended in some directions and brought up to date in relation to current research conclusions. The text is divided into five parts covering natural water supplies, scale formation, corrosion, foaming and priming and analysis and routine testing.

The author, a British feedwater specialist, wrote the book primarily as a modest guide for the "small average" steam plant operator but the text contains rather comprehensive studies. There are included various treatments such as lime-soda process, zeolite or base-exchanger softeners, lime-barium softening, colloidal conditioning and the Budenheim process for the prevention of scale formation. The subject of corrosion is discussed at length and includes many of the contributing factors and the methods of correcting them.

An appendix contains directions for preparing standard solutions used in analyses, Clark's table of hardness, and a table of chemical factors together with conversion tables and a summary of good water conditions.

The text contains 319 pages, size $5^1/_2 \times 8^3/_4$ in., and includes bibliographies and a comprehensive index. Price $5.

Boiler Operators Guide

By Harry M. Spring, Jr.

This is intended as a practical manual of steam boiler operation and maintenance for operating engineers, boiler inspectors and those preparing for license examinations. The designs of typical boilers are included as well as methods of installation, operation and maintenance. Over three hundred typical license examination questions and answers are included.

The book contains 353 pages, 6 × 9 in., with 242 illustrations. The price is $3.

Heating, Ventilating, and Air Conditioning Guide for 1940

This is an authoritative reference manual, now in its eighteenth edition, issued annually by the American Society of Heating and Ventilating Engineers and devoted exclusively to the subjects of heating, ventilating and air conditioning, and related data on refrigeration. It has been compiled by men active in the profession and the allied industries and is arranged in two sections—a Technical Data Section of 46 chapters and a Catalog Data Section on manufacturers' equipment.

The present volume is less bulky and lighter in weight than previous editions, due to condensation and consolidation of text matter, and the use of lighter paper. Although there has been an addition of much new data in old chapters and one new chapter, the result is a volume actually containing more information, but easier to handle and more convenient to use.

There are 1184 pages, 6 × 9 in., illustrated, and the price is $5 for the regular edition or $5.50 for a special thumb-index edition.

Standards of Deaerator and Deaerator Heater Section

This publication by the Heat Exchange Institute complements its standards on Surface and Barometric Condensers and on Steam Jet Ejectors. It contains recommendations on nomenclature, definitions, construction, ratings, accessories and a typical specification planned to assist the designing engineer in furnishing the information necessary for construction of the proper unit.

The price is 75 cents.

Training Procedure

By Frank Cushman

This 225-page book discusses the problems encountered in planning, organizing, operating and maintaining effective training programs in industrial, business and public service organizations. Recognizing that training costs money, it is pointed out that this is likely to be much less costly than where the new employee has to train himself by bothering associates and possibly making serious mistakes. The impracticability of the pre-employment training by outside agencies, for many types of employment, is contrasted with well-tried extension training for employed personnel. The latter is most important where changes in technique or in product are involved.

Human factors and the necessity for upgrading are discussed, fallacies cited and several successful training methods described.

The price of the book is $2.

Interior Electric Wiring and Estimating

By Uhl, Nelson and Dunlap

This is a revised and enlarged edition written in "how-to-do-it" style and covering industrial as well as building and domestic applications. Its 342 pages are fully illustrated and numerous tables and charts are included. The price is $2.50.

CORRECTION

Power Economics for Engineering Students by Prof. R. C. Gorham, is priced at $3.25 not at $4.00 as indicated in our January Review.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Twentieth Century Advance in Efficiencies

Engineering (London) in its April 12 issue prints in abridged form the second part of the Thomas Hawksley Lecture delivered by Sir Leonard Pearce before the Institution of Mechanical Engineers. Part one was reviewed in the March issue of COMBUSTION.

The author outlined the advancements made in the design and operation of power stations in England from 150 lb per sq in. dry saturated at the beginning of the century up to 600 to 650 lb per sq in., 850 to 875 F and feed heating of 300 to 350 F at the present time. Two stations now under construction are designed for 1300 to 1400 lb per sq in. and 950 F at the turbine with feed heating to 400 F.

Fig. 1 illustrates the rise in basic and thermal efficiencies of prime movers together with the rise in actual station thermal efficiencies for stations employing the regenerative cycle. Fig. 2 indicates similar trends for stations employing the reheat cycle. It is significant that since the beginning of this century the overall oper-

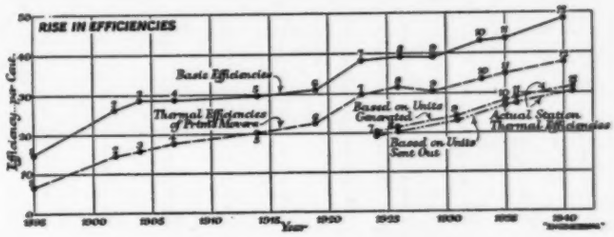

Fig. 1—Efficiencies plotted against years for regenerative cycle

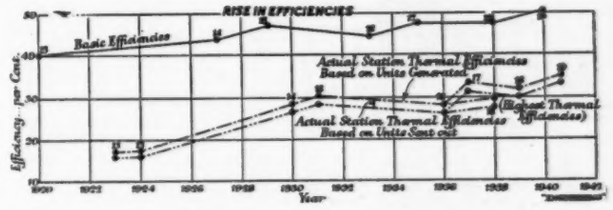
RISE IN EFFICIENCIES
Basic Efficiencies
Actual Station Thermal Efficiencies Based on Units Generated
Actual Station Thermal Efficiencies Based on Units Sent out
(Reheat Thermal Efficiencies)
Efficiency - per Cent.
Year

Fig. 2—Efficiencies plotted against years for reheat cycle
Points 17 and 19 refer to American installations

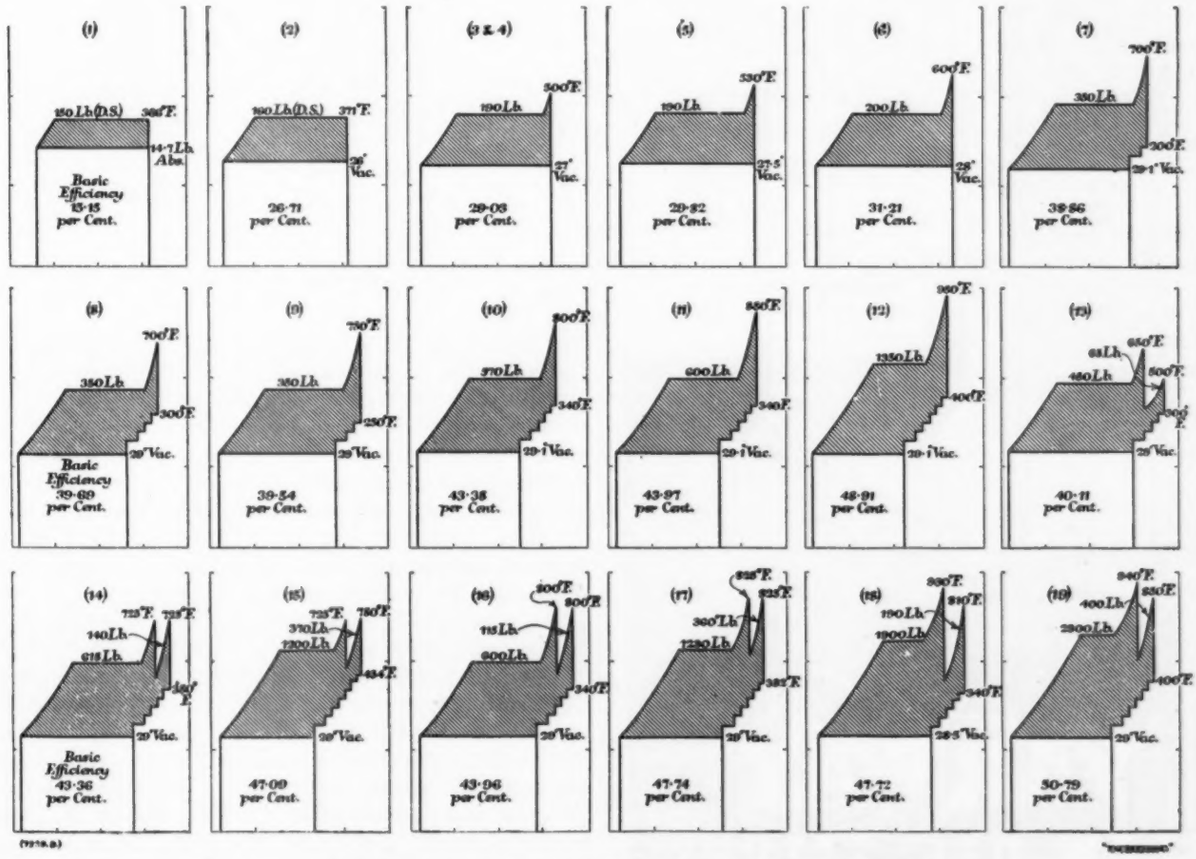

Fig. 3—Temperature-entropy diagrams for heat cycles indicated in Figs. 1 and 2
Nos. 17 and 19 refer to American installations

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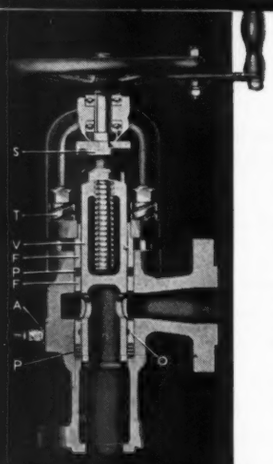

Yarway Seatless Blow-off Valve. Operation: After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

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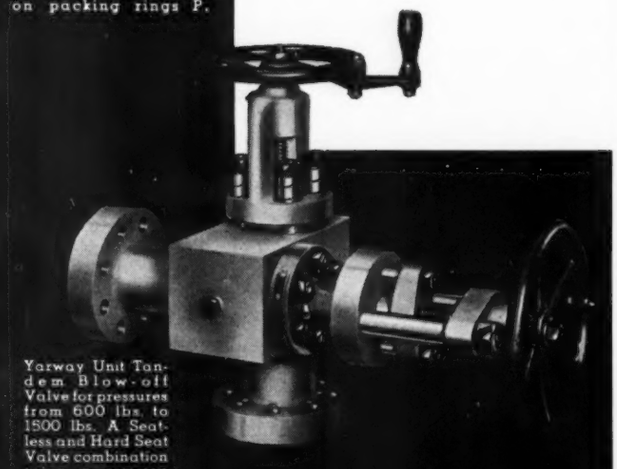


Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

YARWAY

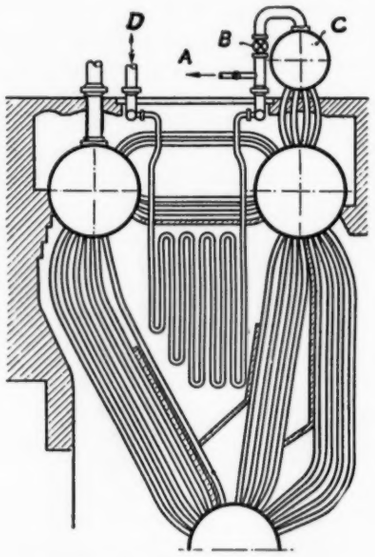
BLOW-OFF VALVES

ating efficiency of power stations has risen from less than 10 per cent to the present level of the order of 30 per cent; and the fact that the actual results are in line with the basic efficiencies shows that these results have been attained largely by improving the steam conditions.

The temperature-entropy diagrams of Fig. 3 conveniently and clearly show the significance of the increase in basic efficiency which has accompanied the improvements in steam conditions for some nineteen heat cycles. The diagrams indicate an improvement in the basic cycle efficiency, over a period of forty years, from about 15 per cent to over 50 per cent.

Maintenance of Steam Temperature

In *Die Wärme* of February 3, Paul Köppe describes a cure for temperature changes in superheated steam lines. The changes occurred during sudden demands upon boilers that served as stand-by units. One such boiler had 5382 sq ft of heating surface, was provided with a pendant superheater and was fired with brown



Arrangement of superheater

coal by means of a stepped grate. During stand-by, the boiler and superheater cooled off because of a certain amount of draft that was maintained to prevent escape of gas into the boiler room and to avoid possible gas explosions within the boiler setting. The steam temperature-surges appeared even when the firing rate was but slowly increased in the stand-by boiler. During stand-by, water condensed and accumulated in the pendant superheater loops, shown in the diagram, and this had to be evaporated to be removed.

To overcome the disadvantages of the pendant superheater additional connections were provided in the superheater piping, as shown in the diagram, and these come into play in the following manner. Immediately upon taking the boiler off the line, steam is drawn from the bleeder connection *A* between the stop valve *B* and the saturated steam connection to the superheater, in the pipe from steam drum *C*. As soon as the boiler ceases to steam, a reversed flow from the main steam line, via connection *D*, is introduced through the superheater and out through the bleeder connection *A*.

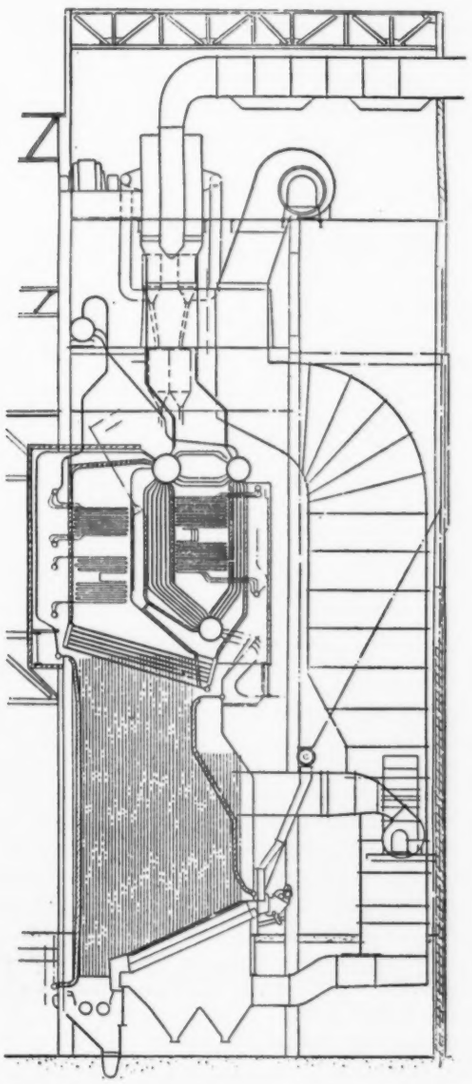
The quantity of reversed-flow steam is controlled so that the temperature of the superheater remains sufficiently great to prevent condensation.

The author points out that this arrangement gives the pendant superheater certain advantages over the type having the elements horizontally arranged in that the means for suspension are much simpler.

In this installation steam used to keep the superheater hot is passed on to the feedwater makeup evaporator which is also served by feed pump exhaust and steam feed from the main turbine-generators. In conclusion the author presents examples indicating how to calculate and arrange for the steam flow required to prevent condensation in the superheater.

Battersea High-Pressure Boiler

Engineering and Boiler House Review for April comments on the new high-pressure extension to Battersea Station of the London Power Company, pointing out that plans call for the ultimate installation of three 100,000-kw turbine-generators, each served by two stoker-fired 550,000-lb per hr steam generating units with steam



Section through high-pressure steam generating unit

— for Central Ohio Light & Power Company

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It proves what can be done — but when the startling performance of the test run goes on day after day, under practical operating conditions, it proves the merit of Askania Control.

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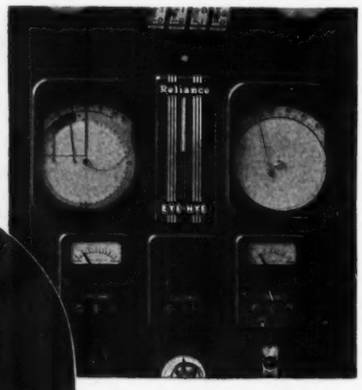

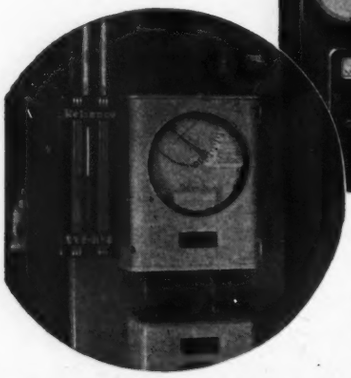

Above—EYE-HYE takes prominent position on panel at Virginia Polytechnic Institute.

Left—Model E-10 EYE-HYE at Case School of Applied Science, Cleveland.

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Boiler Safety Devices since 1884

at 1420 lb pressure and 965 F at the superheater outlet. Each set will consist of a 16,000-kw 3000-rpm high-pressure turbine exhausting at 600 lb to an 84,000-kw 1500-rpm condensing turbine, the reason for the adoption of the intermediate pressure of 600 lb being that the lower pressure turbine can be operated from the 600-lb mains of the first section of the station in an emergency. At present only two boilers and one turbine-generator set are being installed.

A cross-section of one of the new steam generating units is here reproduced from which it will be noted that the design represents a three-drum bent-tube boiler preceded by a straight-tube sectional-header section, serving as a slag screen, with the superheater between the two.

The distribution of heating surface is as follows:

	Square Feet	Per Cent of Total
Boiler	18,603	31.8
Water walls	4,737	8.1
Superheater	14,540	24.8
Economizer	20,713	35.3
Total pressure surface	58,593	
Air heater	170,000	

Self-Priming Centrifugal Pump

In the January 6 issue of *VDI Zeitschrift*, R. Dziallas presents an explanation of the action of a new form of self-priming centrifugal pump with an ejector arrangement. The system employs a combination of a centrifugal pump and two ejectors. Before connecting to the centrifugal pump there is an inverted U-bend in the suction pipe which extends well above the top of the pump and thereby maintains the pump sufficiently full of water when idle. The pump must be initially filled with water up to the U-bend after which it is always ready to run. From then on the operation is as follows:

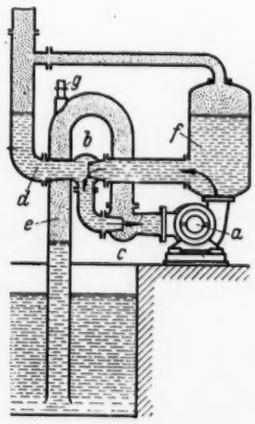

Fig. 1—Deaerating period

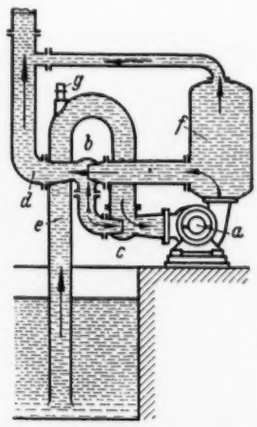

Fig. 2—Delivery period

Upon starting the centrifugal pump *a*, the water is set into motion through both ejectors *b* and *c*, and a flow circuit is established in the direction of pump *a*, air chamber *f* and ejectors *b* and *c*, as shown in Fig. 1. The ejector *c* then functions as an air exhauster since the water leaves the nozzle at high velocity and entrains the air out of suction pipe *e*. The entrained air is discharged by the pump into the air chamber *f*, is therein separated from the water and thence passes through an air discharge pipe into the pressure discharge pipe *d*. The deaerated

water again flows back into the circuit through the ejector *c* to again remove more air from the suction line. In this manner the suction line is soon deaerated, the circuit is filled with water and the pump delivers water as shown in Fig. 2.

The major portion of the delivered water is now forced through ejector *b* to delivery pipe *d*. Finally the air chamber fills up entirely with water so that part of the delivered water passes through the air discharge pipe to the delivery pipe *d*. At this instant a change takes place in the dynamics of the circuit since a suction pressure is set up beyond the nozzle of ejector *b* which causes a reduction of the amount of water flowing through ejector *c*. By a proper proportioning of the nozzles, the water flowing around the circuit may be entirely stopped, at least theoretically. When this occurs the suction pressure of the ejector must be equal to suction pressure of the pump. The ejector *c* is then out of use.

When the pump is shut down the water level within the suction line sinks and air flows from the discharge line into the pump system. In order to avoid completely syphoning out the system, an air valve *g* is provided near the highest point of the bend in the suction line. This valve is equipped with a small lift magnet which is connected in parallel with the electrical circuit to the pump motor. When the motor circuit is broken the magnet is deenergized and drops the air valve into open position permitting the air to flow into the suction pipe, thereby breaking the syphon. The pump system then retains the requisite water while the water level in the suction pipe sinks.

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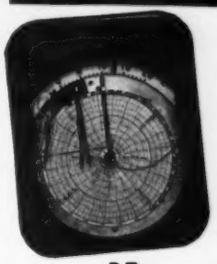

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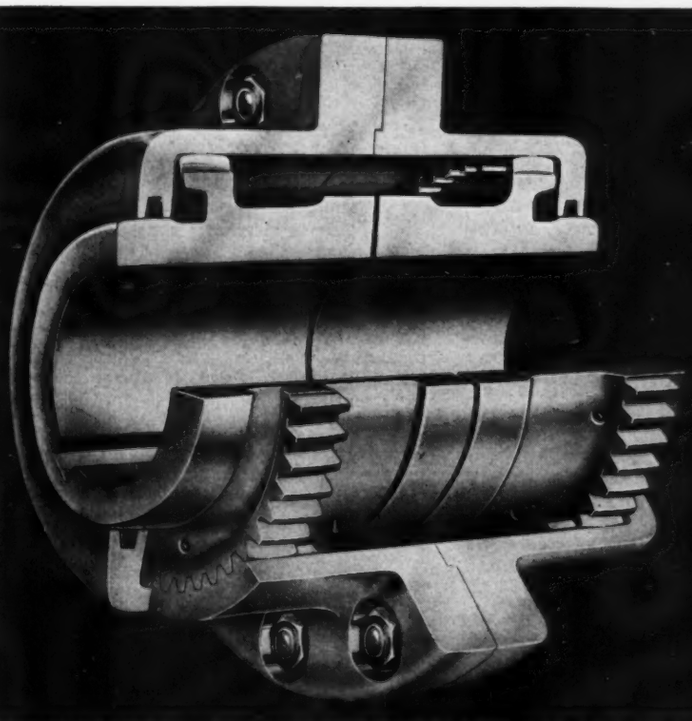

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NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Bearings

Koppers Company has just issued a booklet describing its new Fast's Multiple Oil Film Bearing for which United States rights were obtained last summer. The booklet outlines the history of bearings, discusses the principle of the Fast's bearing, describes and illustrates its design, provides tables of dimensions and load capacities, dimensions of standard bearing housings, recommended shaft sizes, dimensions of lock nuts and proper oil levels. It is stated that these bearings, in a sealed housing, will run continuously for a year on a single filling of oil.

Belts

A new type of leather link belt is described in an illustrated booklet by Alexander Brothers, Inc. In this each link is made from two plies of leather bonded together on the flesh or rough side, producing a solid link with the grain on the outside. The double-ply links are bored and then joined by steel pins. Outside links have counterbored holes to provide a shelter for the end of the pin.

Combustion Control

Basic problems in efficient boiler operation and details of the methods by which the Republic-Smoot automatic combustion control solves these problems are discussed in a new 94-page data book, No. S-21, just published by Republic Flow Meters Co. This book, a text on modern combustion control methods, includes a number of installation reports on specific plants, illustrated with diagrams and presenting performance data and evidence of the benefits resulting from the installation of combustion control for various sizes of boilers, different types of fuel firing and all load conditions.

Electrical Precipitation

An attractive 22-page illustrated booklet covering the history, development and principles of the Cottrell process of electrical precipitation of solids from flue gases, has been issued by the Research Corporation and its affiliate, Western Precipitation Corporation. Definitions covering the specific usage of various terms are included and numerous typical installations are shown.

Flow Meters

The Brown Instrument Company has just published a new catalog, No. 2203, entitled "Brown Mechanical Flow Meters," which covers the company's line of mechanical flow meters, indicators, recorders and air-operated flow controllers. Their operation, with particular reference to the automatic recording planimeter, integrator dial and inter-related range tube types, is included.

Oil and Moisture Separators

A new 8-page bulletin, No. 2950, has just been published by Cochrane Corporation on baffle-type moisture and oil separators for use in vertical or horizontal steam, gas and air lines. It contains cross-sections photographs and line drawings of the three popular types of line separators built for use on lines ranging from $^1/_2$ to 30 in. in diameter. Complete design, dimension and constructional data are given, as well as list prices. Data on proper drainage, gage fittings and auxiliary equipment are also included.

Proportioning Pumps

D. W. Haering & Co., in a recent bulletin, announces the development and introduction of the new Nelson chemical proportioning pump for which it has been appointed national distributor. This pump is applicable to water treatments, oil treatments and may also be applied to continuous sampling wherever reciprocating control is available. The pump is fully described.

Traps

Yarnall-Waring Company has lately brought out a revised and enlarged edition of its bulletin on "Yarway" Impulse Steam Traps. It points out the need for traps, their selection, special designs, installation and operating details. Capacities, prices, weights and dimensions are given, together with an explanation of how to determine steam trap efficiency.

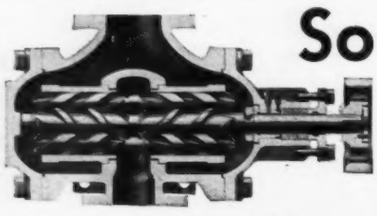
Turbines

A new 28-page illustrated booklet describing general purpose impulse turbines for condensing or noncondensing service and designed especially for industrial and central-station applications, has just been announced by the Westinghouse Electric & Manufacturing Company. The sizes of these turbines, known as type C, cover the range from 5 to 1500 hp and for inlet steam pressures up to and including 600 lb per sq in. and 750 F.

Complete descriptions of the turbines are given with emphasis on the scheme of "dual protection" incorporated to prevent accidents or service outages due to overspeed. Mechanical parts are outlined, explained and illustrated by means of marked pictures. Special features are treated similarly in another section of the booklet. A list of standard equipment and accessories furnished with the turbines gives useful information. General material specifications are tabulated, which include all necessary information needed by the potential customer to select the turbine most suitable to his needs. There is also a section on accessories.

V-Belts

In a recent 24-page catalog on fractional-horsepower V-belt design, The B. F. Goodrich Company has explained the problems of selecting a V-drive using stock belts in terms understandable to a purchaser or operator without professional engineering training. There is also a discussion of V-belt practice, including such subjects as take-up, slack-off, tension, idlers, effect of oil, effects of fumes and gases, moisture, dust, and temperature, guards or shields, use of belt dressing, storage, riding position of belt and installations.



So they bought *another* IMO

The pipe line company which owns the portable IMO oil pumping unit here shown recently ordered a duplicate. Other repeat orders just received are fuel oil service, lube oil service and fuel oil transfer pumps for two more Maritime Commission ships, lube oil pumps for a turbine manufacturer, fuel oil service pumps for an oil burner manufacturer, lube oil pumps for a refinery, fuel oil pumps (a total of 18 by ones and twos in six years) for a gas company, etc., etc. De Laval-IMO oil pumps can be run at standard motor and turbine speeds. *Ask for Catalog I-58.*

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